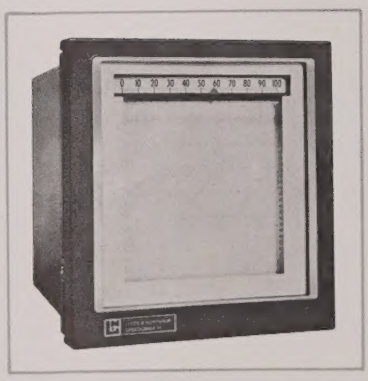
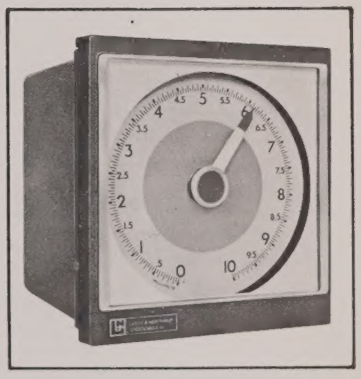
LEEDS & NORTHRUP
A UNIT OF GENERAL SIGNAL

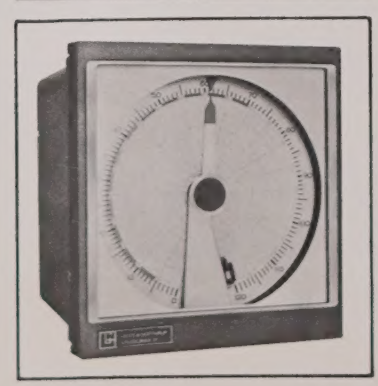
2573

DIRECTIONS 077990 • ISSUE 20

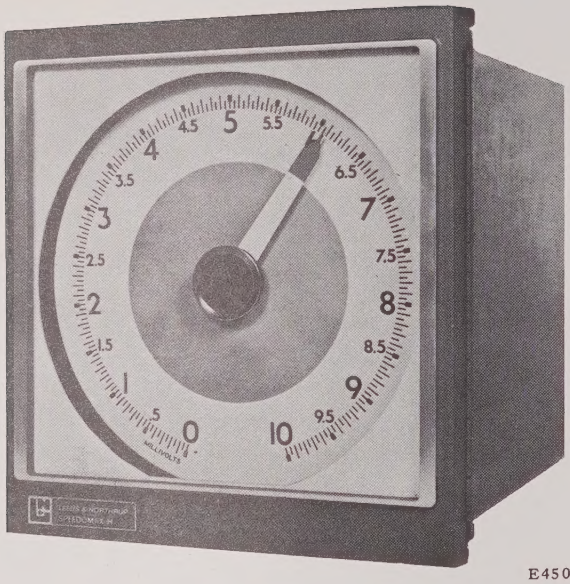
SPEEDOMAX® H MANUAL





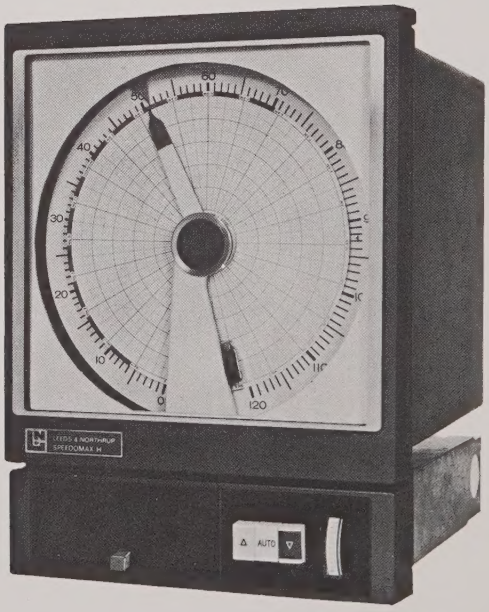


H



E4504

SPEEDOMAX H INSTRUMENT



E4505

SPEEDOMAX H INSTRUMENT WITH SERIES 80 CONTROLLER IN LOWER CASE

Leeds & Northrup trademarks used in this publication are registered in the U.S. Patent Office and include Speedomax, Rayotube, and Thermohm.

Printed in U.S.A.

It is the purpose of this manual to meet your operating and/or service requirements for L&N equipment by providing complete and accurate information. Your comments or suggestions to further improve this manual will be welcomed. Send to: Manager, Engineering Coordination and Services, MD 269, Leeds & Northrup Company, North Wales, PA 19454

Copyright, 1979, Leeds & Northrup Company

CONTENTS

Section — Page

INTRODUCTION v
SPECIFICATIONS vi

PART I — INSTALLATION AND OPERATION

Section A—INSTALLATION

Unpacking A–1
Mounting A–1
Temperature Limits A–1
Wiring Connections A–1

Section B—PREPARATION FOR OPERATION

Chart Installation And Pen Preparation B–1
Scale, Pointer, And Pen Lineup B–3
Instrument Start-Up B–5
Adjust Amplifier Gain B–5
Adjust Damping B–5
Zero-Offset Adjustment B–5
Amplifier Grounding B–5

Section C—OPERATING ADJUSTMENTS

Rheostat Adjustments C–1
Rayotube Instruments C–1
Gas Analysis Instruments C–1

Section D—CONTROL AND ALARM FEATURES

Control Assembly D–1
Set Point Setter D–1
Stationary Switches D–2
Control Assembly Wiring Diagram D–2
Switch Characteristics D–3
Preliminary Control Assembly Adjustments D–3
Control Assembly Wiring Arrangements D–4

Section E—ROUTINE MAINTENANCE

Care Of Pen And Ink Supply E–1
Cleaning And Lubricating E–2
Recorder Inks E–6

PART II — SERVICING AND TROUBLESHOOTING

Section F—REMOVAL AND INSTALLATION OF PARTS

Tools F–1
Range Card F–1
Amplifier F–1
Regulated Power Supply F–2
Drive Cord Replacement F–2
Slidewire Assembly F–4
Balancing Motor F–4
Control Assembly F–5
Chart Motor F–6

CONTENTS — Cont.

Section **Page**

Section G—MECHANICAL SERVICING

Contact Force Adjustments G–1
Model R Chart Drive G–1
Model R Pen Bracket G–2
Clutch Adjustments G–2
Motors G–3
Balancing Motor Gear Mesh G–3
Model S Pen Force Adjustment G–3

Section H—CALIBRATION

Preliminary H–1
Scale, Pointer, And Pen Lineup H–1
Instrument Dead Band H–1
Zero-Offset Adjustment H–2
Calibration Procedure H–3
EMF Potentiometer Circuit H–3
Thermocouple Potentiometer Circuit H–3
Bridge Instruments H–6

Section J—LOCATING TROUBLE

Interference J–1
Preliminary Checks J–2
Isolation Tests J–2
Troubleshooting Measuring Circuit J–4
Troubleshooting Cables J–4

Section K—AMPLIFIER TROUBLESHOOTING

Test Equipment K–1
General Test Information K–1

PART III — TECHNICAL INFORMATION

Section L—MISCELLANEOUS ITEMS

Null-Balance Measuring System L–1
Speedomax H Characteristics L–1
Thermocouple Circuit L–2
Range Cards/EMF Failsafe/Failsafe Error L–2
EMF Failsafe L–6
Failsafe Error L–6
The Regulated Power Supply L–7

Section M—TWO-POSITION CONTROL

Two-Position Single Point Control M–1
Two-Position Differential-Gap Control M–2

PART IV — APPENDIX

Section N—FIELD CHANGES AND OPTIONAL FEATURES

Range Change N–1
Chart Tear-Off Device N–1
Chart Speed Change N–1
Other Optional Features N–1

INTRODUCTION

USE OF THE MANUAL.....

This manual has been prepared to serve as both an instruction book for operation and maintenance, and as a source of general information on Speedomax H instruments. For ease in use, all information needed for placing the instrument in service, and for performing routine maintenance, is given in the first part of the manual. Servicing instructions given in Part II will, of course, be consulted as the need arises. Part III describes the basic characteristics of the instrument and, by contributing to an understanding of its capabilities and limitations, should aid in its proper application.

SCOPE.....

Models—The manual covers the three models comprising the Speedomax H line of instruments—the Model S (strip chart) recorder; Model R (round chart) recorder; and Model R (round scale) indicator. These three models all employ the same basic mechanism and differ only in the kind of recording or indicating assembly which is mounted on the basic structure. Therefore, all information except that dealing specifically with the front assemblies, will apply to all Speedomax H instruments, regardless of model.

Cases—The Speedomax H instrument may be furnished by itself or with an auxiliary case. The auxiliary case usually contains control or other circuitry that works in conjunction with the instrument. Both types are illustrated on the inside cover page. Note, however, that only those components located in the case of the measuring instrument itself are considered here. For information on the lower case unit, the user is referred to other booklets supplied with the equipment.

Measuring Circuits—This manual covers those circuit types most frequently encountered. Where special arrangements are furnished, a supplementary sheet or booklet is supplied, if required. Where such special instructions conflict with this manual, they shall be considered authoritative.

Multipoint Recorders—Information pertaining to multipoint features is contained in the Speedomax H & W Manual for Multipoint Recorders, Directions 177304.

IMPORTANT

When requesting information about this instrument, always furnish the instrument serial number. This number is marked on the nameplate inside the instrument case.

SPECIFICATIONS . . . *Specifications meet or exceed performance requirements of ANSI Spec. C39.4*

ACCURACY RATING—±0.3% of electrical span where Suppression Ratio is 2 or less; ± (0.3 + 0.1 (SR-2))% of electrical span where Suppression Ratio (SR) is greater than 2. (Suppression Ratio = low end of span, in mV, divided by span, in mV.)

DEADBAND—0.15% of span.

SPAN STEP-RESPONSE-TIME RATING—5 seconds or 1 second nominal, full scale.

MEASURING-CIRCUIT CURRENT SOURCE—Supplied by a-c line, rectified, and regulated by Zener-diode circuit.

POWER REQUIREMENTS — 120 V, 60/50 hertz, as specified. Power consumption—40 volt-amperes.

CASE—Gray, cast aluminum, 12″ (h) x 11″ (w) x 13″ (d) (305 x 279 x 330 mm).

SPEEDOMAX H LIST NUMBER

(1) MODEL	(2) MEASURING CIRCUIT	(3) CONTROL FORM	(4) RANGE	(5) POWER SUPPLY	(6) CHART SPEED	(7) OPTIONAL FEATURES
□□□	— □□□	— □□□	—□□□□	— □	— □□□	—□□□—□□□

BASIC FEATURES

(1) MODEL	Model R Indicator	**100**	Model R Recorder	**200**	Model S Recorder	**300**
(2) MEASURING CIRCUIT	Span-Step-Response-Time Rating		Solid-State Amplifier [1]		Solid-State Moderate Impedance Amplifier [2]	
	5 seconds:		1□□		3□□	
	1 second:		1□□ [3]		3□□ [3]	
(3) CONTROL FORM	For no control, insert **000**. A wide choice of two-position and proportioning control forms is available.					
(4) RANGE	As specified					
(5) POWER SUPPLY	120 volts, 60 hertz	**6**	120 volts, 50 hertz	**5**		

(6) CHART SPEED	Model R Indicator	Insert **000**.					
	Model R Recorder	24 hrs/rev.	**024**	8 hrs/rev.	**008**	48 min./rev.	**048** [4]
	Model S Recorder	1 in./hr	**001**	15 in./hr	**015**	240 in./hr	**240**
		2 in./hr	**002**	20 in./hr	**020**	360 in./hr	**360**
		3 in./hr	**003**	30 in./hr	**030**	480 in./hr	**480**
		4 in./hr	**004**	60 in./hr	**060**		
		6 in./hr	**006**	120 in./hr	**120**		
		12 in./hr	**012**	180 in./hr	**180**		

[1] For use with spans from 1 to 1000 mV, with a maximum source impedance of 2000 ohms for rated performance.

[2] For use with spans from 1 to 1000 mV, with a maximum source impedance of 25,000 ohms for rated performance.

[3] Specify Optional Feature 601 for 1-second response time

[4] For 60-hertz operation only.

(7) TYPICAL OPTIONAL FEATURES AND OPERATING AIDS

	In./Hr	Element 50/60 Hz	In./Hr	Element 50/60 Hz
Dual Chart Speeds: A second chart-drive motor can be provided in the Model S recorder for a fast chart speed. Switch has three positions: "Fast", "Off", "Slow". The slower of the two speeds is specified as the sixth element of the basic number, the faster speed by an appropriate element number, from the table, as a suffix.	4	**168**	120	**160**
	6	**170**	180	**162**
	10	**150**	240	**164**
	12	**174**	360	**166**
	20	**176**		
	30	**152**		
	60	**156**		
	90	**158**		

Chart Motor Switch. For Model S only. Toggle-type on-off switch mounted inside recorder case.		**080**
Multiple Chart Speed Changer. Provides 10 fixed chart speeds from 1 to 240″/hr.		**509**
Off-Scale Limit Device. For recorders only. Operates at low and high ends of scale to provide reduced torque from balancing motor and (optionally) chart shut-off. Normal torque is restored and chart starts when recorder returns on scale.	With chart shut-off	**026**
	Without chart shut-off	**027**
Fluorescent Illumination of Chart and Scale. For Model S only. 6-watt fluorescent lamp mounted in recorder and connected to terminal board. Lamp is wired to go on and off as instrument is switched on and off, but provision is made for connecting an external switch or external power supply.		**038**
Chart Tearoff Device. For Model S only. Includes tearoff bar and a special reroll mandrel with tape and clip to assure positive chart travel.		**005**
Tilting Chart Table and Tearoff Device. For Model S only. In addition to tearoff bar, includes folding chart table which extends out 40° from vertical to facilitate jotting notes.		**095**

Carrying Handle	**521**	**Line Cord**	**522**
Rubber Bumper "Feet"	**523**	**Support Stand**	**524**

Section A — INSTALLATION

UNPACKING

Remove the instrument from its packing case, and remove any shipping ties, clamps, or packing material. Any instructions given on the tags attached to the instrument should be carefully followed and such tags removed.

The door can be opened by depressing the catch release button, identified in Figs. A1 and A2. The shipping screw, also shown in these figures, must be removed before the hinged mechanism can be swung out. In swinging out the mechanism, use the handle at the lower right-hand corner, Figs. A1 and A2.

MOUNTING

The instrument is arranged for flush mounting only. Figs. A3 and A4 give all necessary mounting dimensions. Fig. A4 also applies when equipment other than a controller is housed in the lower case.

As noted in Figs. A3 and A4, the mounting studs supplied are suitable for use with panels up to ⅜″ thick. When mounting the instrument on panels thicker than this, the longer studs required are to be supplied by the user.

The instrument case should be connected to a good earth ground unless specific exception is made on the instrument wiring diagram. The use of the ground stud on the terminal board (see Fig. H3) will effect such grounding when the instrument is mounted on a metal panel that is properly grounded. Where an insulated panel is used, connection should be made from the ground stud to an earth ground bus.

TEMPERATURE LIMITS

The instrument should not be installed in locations where the ambient temperature exceeds the range 16° F to 122° F (−9° C to 50° C).

WIRING CONNECTIONS

Detailed wiring connections are shown on one or more diagrams supplied with the equipment. Where a lower case unit is included, refer to the manual for that unit.

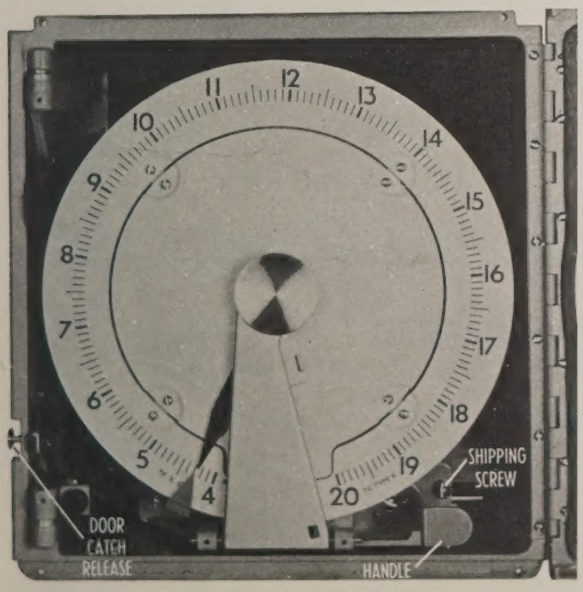
All wiring diagrams are self-explanatory. In making connections, however, the user is advised to observe the procedures and precautions which follow.

As indicated in Fig. A3, the cover plate can be removed to permit access to the instrument terminal board. All connections are usually made to the rear of this terminal board. If control or other auxiliary unit is used in the lower case, connections to the terminal board on the back of this case may also be required.

Connect power supply of the proper voltage and frequency as specified on the nameplate which is located at the inner left side of the instrument case. In making the power connection, note the following:

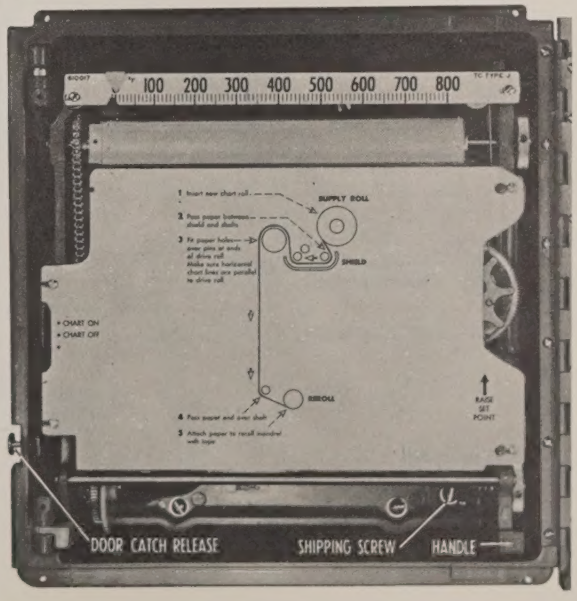
(1) The power supply voltage must be within the limits 107–127 V ac.

(2) The grounded side of the power line must be



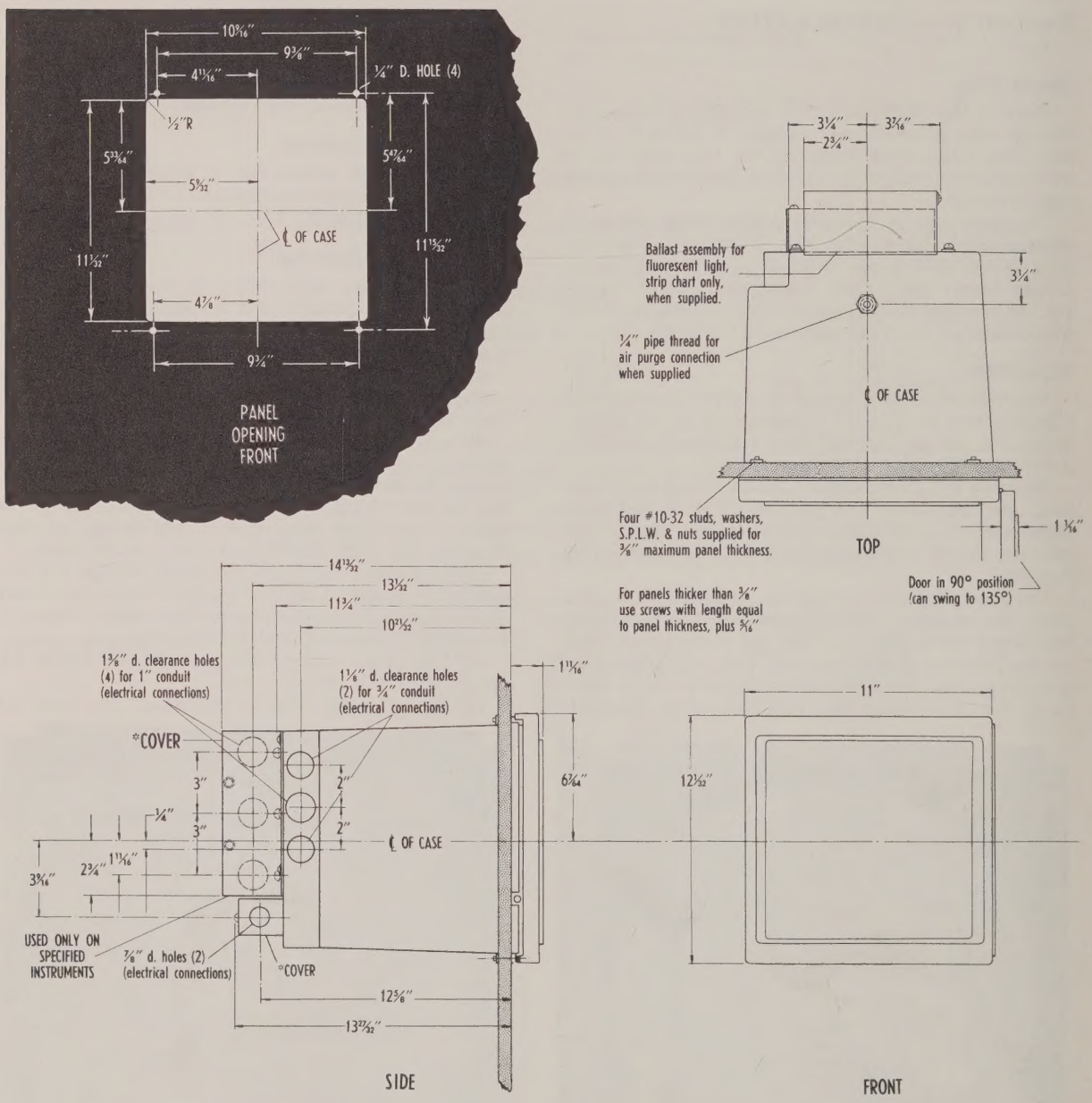
E4506

Fig. A1 — Model R recorder.



E4507

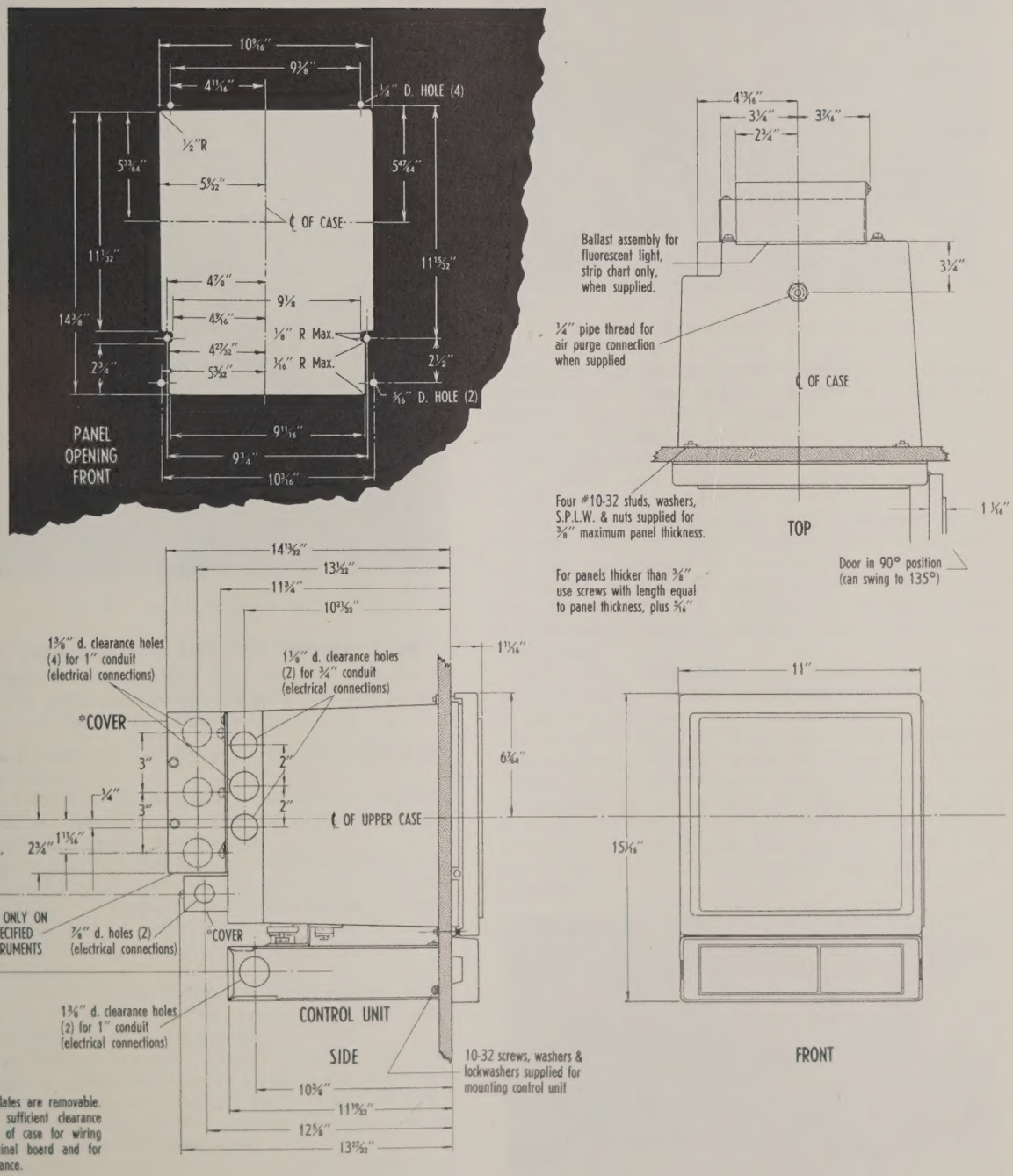
Fig. A2 — Model S recorder.



*Cover plates are removable. Provide sufficient clearance in rear of case for wiring to terminal board and for maintenance.

DE4508

Fig. A3 — Outline and mounting dimensions for Speedomax H instrument.



*Cover plates are removable. Provide sufficient clearance in rear of case for wiring to terminal board and for maintenance.

DE4509

Fig. A4 — Outline and mounting dimensions for Speedomax H instrument with auxiliary case mounted underneath.

connected to the L2 terminal of the terminal board. Use an isolating transformer if one is required, to permit grounding of the L2 terminal.

(3) Power to all parts of the measuring instrument is supplied through a power fuse (1-ampere slow blow—L&N Part No. 014049) and switch located on the upper right side of the case, Fig. B11. However, this switch does not control the power to control elements. Therefore, when control features are included, it is necessary to provide a separate fused switch in the power line external to the instrument. Allow enough fuse capacity for both measuring and control equipment. When a controller is present, 3-ampere fusing is usually sufficient. The amplifier is fused separately through a 0.2-ampere slow blow fuse (L&N Part No. 014068).

Connect the primary element, i.e., the resistance or voltage source being measured, to the terminals as shown on the diagram. Observe any instructions supplied with the primary element. Although no special precautions are usually required, it may be necessary in some installations to shield the primary element leads or to route them so as to avoid strong fields produced by transformers, electric welding equipment, induction heaters, etc. If the input leads are shielded, and if this shield is not grounded, it should be connected to the negative (—) input terminal on the recorder terminal board.

Where the instrument is used for measurement on high-voltage equipment, e.g., thermocouple temperature measurement of transformers, generators, etc., one side of the primary element should be grounded at the high-voltage equipment if the measuring circuit arrangement permits such grounding. This is to protect both personnel and instrument in case of high-voltage breakdown to the primary element.

The instrument case should be grounded unless specific exception is made on the wiring diagram.

If a controller or other auxiliary unit is used in conjunction with the Speedomax instrument, connections to the terminal board on the back of this case will also be required. Refer to the drawing supplied with the equipment.

For information requiring wiring changes for reversed-range emf range cards or for thermocouple and Rayotube range cards, refer to the appropriate heading under Range Cards in Section L.

Section B — PREPARATION FOR OPERATION

E4510

Fig. B1 — Installing Model R chart.

CHART INSTALLATION AND PEN PREPARATION

Important: While preparing the pen, take care not to bend or otherwise damage the penpoint. For proper inks, see Section E, Recorder Inks.

Model R Recorder — Install the chart and prepare the pen as follows.

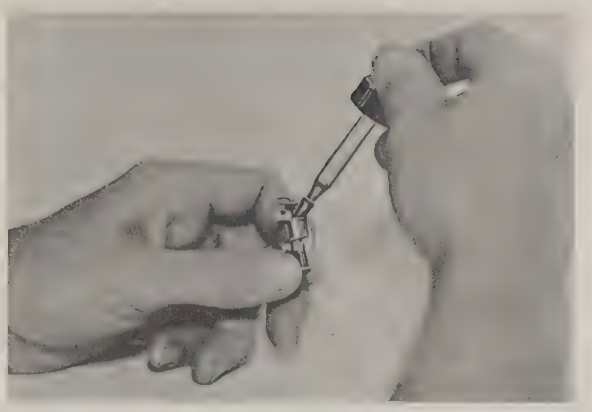
Install Chart — The number of the Leeds & Northrup chart to be installed in this recorder is marked on the nameplate inside the recorder case.

Grasp the pen bracket knob and pull the bracket forward to the position shown in Fig. B1. A spring-loaded stop is provided to hold the bracket in this position. The bracket can be swung down completely by being pulled past the stop; however, this is not necessary for chart installation.

Fit the center hole of the chart over the hub as shown in Fig. B1. Then close the pen bracket, turning the knob until it snaps in to engage the shaft.

When the pen bracket is back in position, the chart is pressed against the knurled edge of the drive disk by the pressure roller. Turning the recorder on energizes the chart drive motor, causing the drive disk to rotate the chart counterclockwise.

The orientation of the round chart on its platen can be adjusted at any time. Simply swing out the pen bracket as directed in the second paragraph of this subsection and rotate the chart so that the pen will be on the correct time line when the bracket is swung back.



E4512

Fig. B2 — Filling Model R pen.

Fill Pen — Slide the pen reservoir down in the clip and use the dropper to fill it with ink as illustrated in Fig. B2. Fill to ⅛″ from the top of the reservoir. Then push the reservoir up in the clip so that it bears firmly against the gasket. Before replacing the pen on its carriage, prime it in accordance with the instructions which follow.

The Model R pen can also be filled in place on the recorder. Swing the pen bracket out to the spring stop and slide the reservoir down in the clip to permit filling.

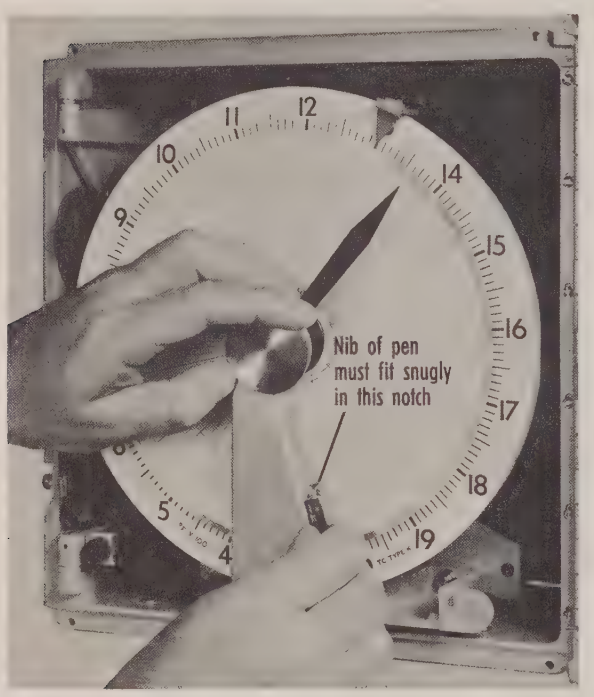
The pen must not be inverted after it is filled, since the ink would leak from the vent tube. Always remove the pen before swinging the pen bracket down past the spring stop.

Prime Pen — The Model R pen must be primed after the initial filling — that is, the pen capillary must be filled to start the ink flow. This process need be repeated only when the capillary is emptied during cleaning or if the capillary is allowed to run completely dry. For this reason, always refill the pen before it is entirely empty.

To prime the pen, squeeze the ink dropper bulb and fit the spout of the dropper over the penpoint as shown in Fig. B3. Slowly release the bulb until ink from the pen starts to run into the dropper. Then remove the dropper.

E4514

Fig. B3 — Priming Model R Pen.



E4516

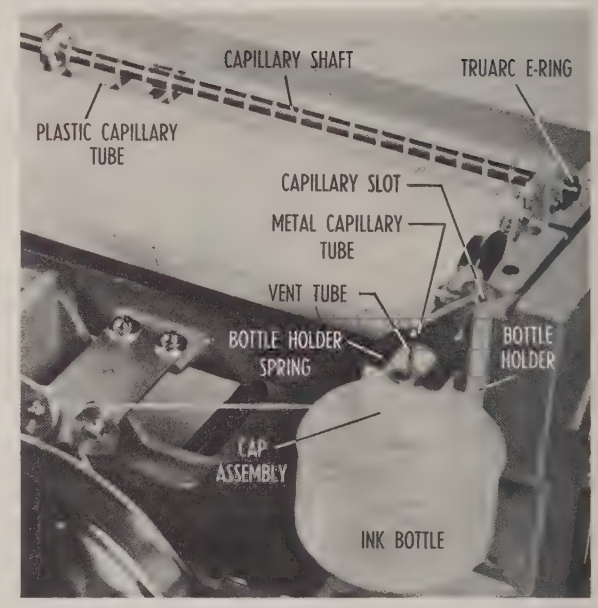
Fig. B4 — Installation of Model R Pen.

Install Pen — To install the pen, swing the pen bracket out to the spring stop, just as for chart installation. Then slide the pen onto its carriage as shown in Fig. B4. To remove the pen, reverse this procedure.

Model S Recorder — Prepare the Model S pen and install the Model S chart in the following manner.

E4779

Fig. B5 — Installation of cap assembly on ink bottle.



E5240

Fig. B6 — Rear view of hinged casting of Model S recorder, showing ink bottle and bottle holder.

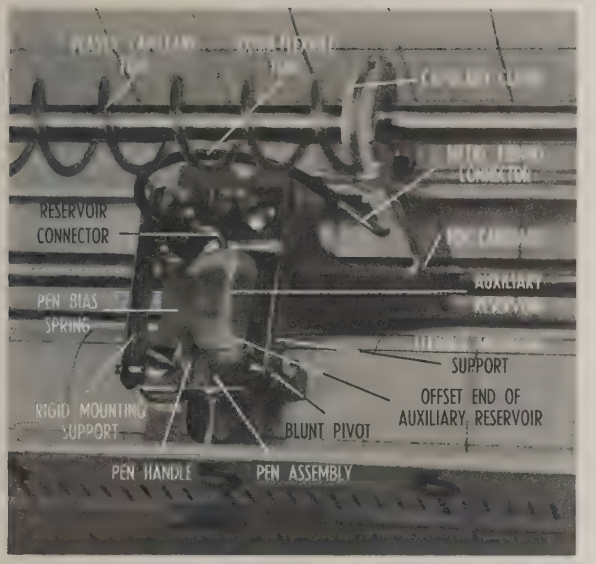
Install Ink Bottle — Remove the ink bottle from its shipping container. Then replace the bottle cap with the cap assembly, Fig. B5, containing the metal capillary and vent tubes, and gasket. Leave the cap somewhat loose. Insert the ink bottle, Fig. B6, into the bottle holder by raising the bottle holder spring; rotate the bottle until the key in the base of the bottle seats itself in the keyway in the bottle holder. Position the metal capillary tube so that it points toward the capillary slot. Then tighten the cap without disturbing the orientation of the metal capillary tube. Connect the plastic capillary tube to the bottle by forcing it over the swaged end of the metal capillary tube.

Connect Pen To Auxiliary Reservoir — Unfasten the auxiliary reservoir, Fig. B7, from the pen carriage. Moisten the capillary end of the pen (supplied with the recorder accessories) with a dampened cloth, paper towel, or paper tissue. Then insert this end of the pen into the offset end of the auxiliary reservoir so that the offset fits over the top of the pen. Rest the pen and auxiliary reservoir on the pen carriage, taking care not to damage the penpoint.

Prime Pen — The pen must be primed before initial use, after any stoppage of ink flow, such as that resulting from air entering the capillary system through an opening or break in the system, after the system has been allowed to run dry, or after the system has been emptied for cleaning purposes.

To prime the pen proceed as follows:

Turn the pen upside down so that the penpoint is tilted up from the horizontal about 45 degrees, as shown in Fig. B8. Then place an absorbent material such as a paper towel, paper tissue, or cloth, under the penpoint.



E5241

Fig. B7 — Top view of hinged casting of Model S recorder, showing pen carriage and pen assembly. Reservoir connector may vary in shape from that shown.

While holding the pen in the above position, close the vent tube, Fig. B6, with the index finger while at the same time gently squeezing the ink bottle with the thumb and middle finger to force ink through the capillary system into the auxiliary reservoir.* Keep the penpoint titled up until the reservoir is as full as it can possibly get in this position.** The penpoint can now be lowered. Keep squeezing the ink bottle until the ink starts to flow out of the penpoint. After the ink starts to flow, remove the index finger from the vent tube and then release the pressure on the ink bottle.

When the ink starts to flow, it should squirt out of the penpoint in a thin stream. If it comes out in drops, then a restriction is present in the system. Such a restriction could be located in the penpoint or it could be caused by crimping of the extra-flexible or the plastic capillary tube, Fig. B7. Remove the restriction by uncrimping the tubes and/or by cleaning the penpoint as directed in Section E.

Install Pen — Grasp the pen handle, Fig. B7, and insert the blunt pivot of the pen into the hole in the flexible mounting support of the pen carriage. Using the pen, deflect the flexible mounting support so that the other pen pivot can be inserted into the hole in the rigid mounting support. While installing the pen, take care not to bend the pen bias spring and/or the flexible mounting support more than necessary.

Install Chart — Install the chart by following the steps illustrated in Fig. B9.

If the recorder is equipped with a chart tear-off device, refer to the Appendix since the chart installation procedure will differ somewhat from that shown in Fig. B9.

Check Penpoint Force — The force of the penpoint against the chart should be between 10 and 15 grams. The force will be between these limits if, with the pen removed from the pen carriage, both edges of the pen bias spring are approximately aligned with the top line of the pivot holes in the rigid and flexible mounting supports of the pen carriage. If the force is too light, causing excessive pen skipping, bend the pen bias spring towards the top of the recorder; if it is too great, causing the pen to pick up paper fibers and become clogged or even to tear the chart, bend the spring towards the bottom of the recorder.

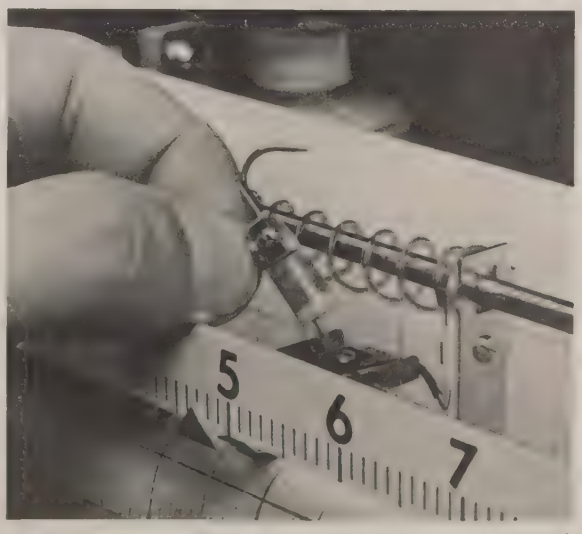
When properly mounted, the pen will swing freely on the pivots and the penpoint will bear against the chart with sufficient force to assure proper inking at all times. The flexible mounting support should exert enough force on the blunt pivot so that there is no shake or backlash between the pen assembly and the mounting supports of the pen carriage.

SCALE, POINTER, AND PEN LINEUP

All Speedomax instruments are completely adjusted and tested before leaving the factory and should be in perfect operating condition when received. It is advisable, however, to make the following simple check at the time of initial installation.

With the instrument turned off, remove the measuring slidewire cover and grasp the hub of the slidewire contact arm as shown in Fig. B10. Turn the arm to bring the measuring pointer downscale until the mechanical stop is reached. Under this condition the pointer should be at the low limit mark (dot) below the calibrated part of the scale, and the pen should be on the first line of the chart (if the instrument is a recorder).

If the instrument does not meet the foregoing requirement, the lineup should be corrected. Refer to Section H.

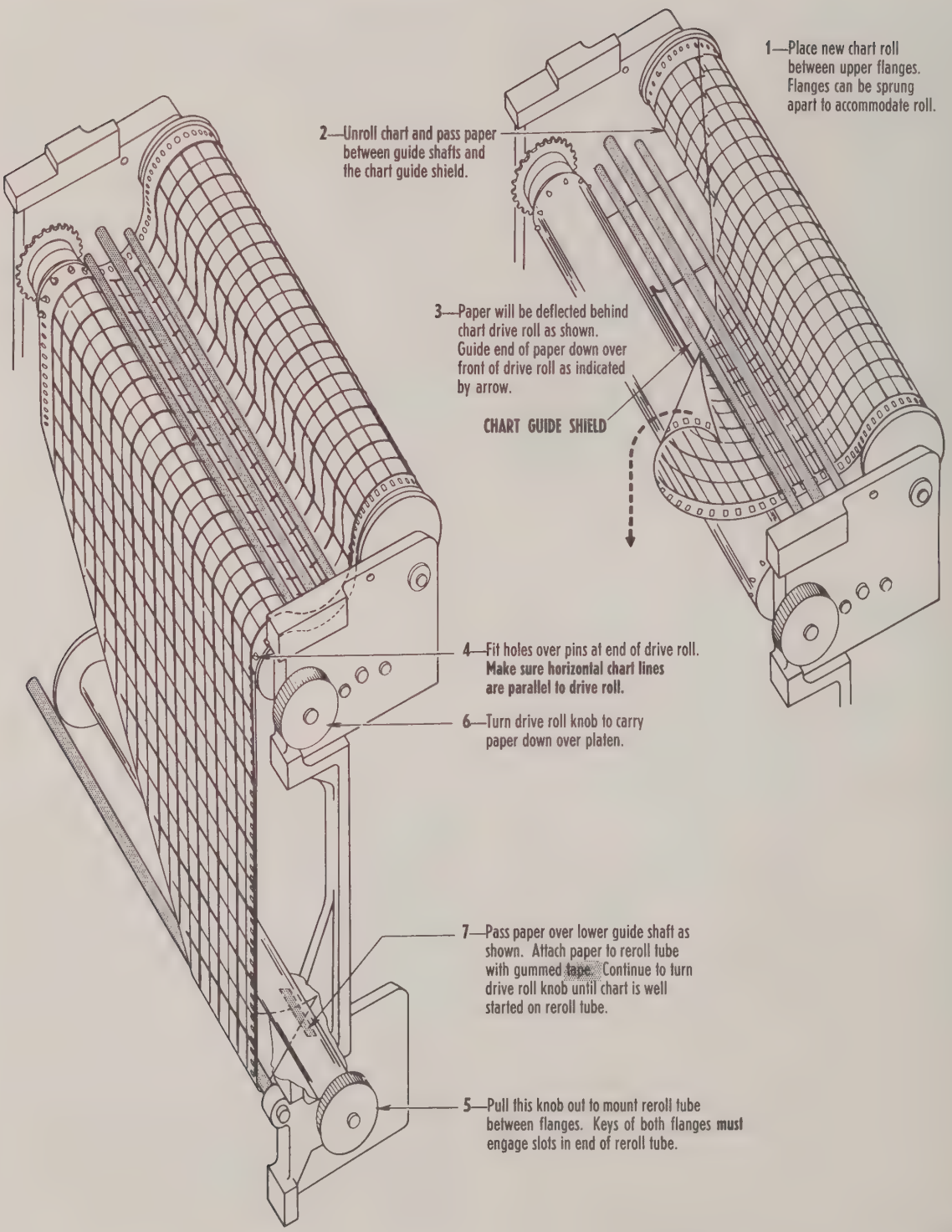


E5242

Fig. B8 — First step of pen priming procedure.

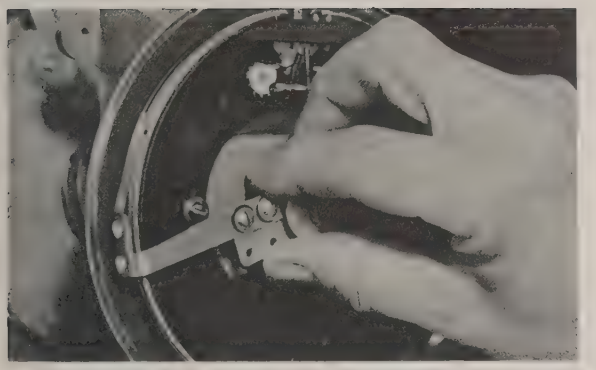
*An alternative method is to use the syringe shipped with each recorder by forcing the plastic tube over the pen tip and aspirating the entrapped air.

**A bubble of air should exist in the auxiliary reservoir so that pen skipping will not occur at fast traverses of the penpoint across the chart.


1—Place new chart roll between upper flanges. Flanges can be sprung apart to accommodate roll.
2—Unroll chart and pass paper between guide shafts and the chart guide shield.
3—Paper will be deflected behind chart drive roll as shown. Guide end of paper down over front of drive roll as indicated by arrow.
CHART GUIDE SHIELD
4—Fit holes over pins at end of drive roll. Make sure horizontal chart lines are parallel to drive roll.
6—Turn drive roll knob to carry paper down over platen.
7—Pass paper over lower guide shaft as shown. Attach paper to reroll tube with gummed tape. Continue to turn drive roll knob until chart is well started on reroll tube.
5—Pull this knob out to mount reroll tube between flanges. Keys of both flanges must engage slots in end of reroll tube.

AE4511

Fig. B9 — Installation of Model S chart.



E4517

Fig. B10 — Manual rotation of slidewire shaft.

INSTRUMENT START-UP

After completion of the preparations as instructed to this point, the instrument may be placed in operation. Place the power on-off switch, Fig. B11, in the ON position. Note that this switch does not control power to the lower-case unit if provided.

ADJUST AMPLIFIER GAIN

After instrument start-up and a warm-up of at least two minutes with the instrument measuring the normal input signal, observe the instrument sensitivity. Then, if necessary, readjust the setting of the amplifier gain control, Fig. B11, using a small screwdriver inserted through the hole in the amplifier cover.

The optimum gain setting is that setting which gives maximum instrument sensitivity without causing "hunting"—that is, pen or pointer oscillation. If oversensitivity, characterized by hunting, or insensitivity is noted, readjust the gain control as follows:

For spans between 1 and 50 mV, set the gain switch in the high-gain position and adjust the amplifier gain control for optimum sensitivity.

For spans between 20 and 1000 mV, repeat the above procedure but with the amplifier gain switch in the low-gain position.

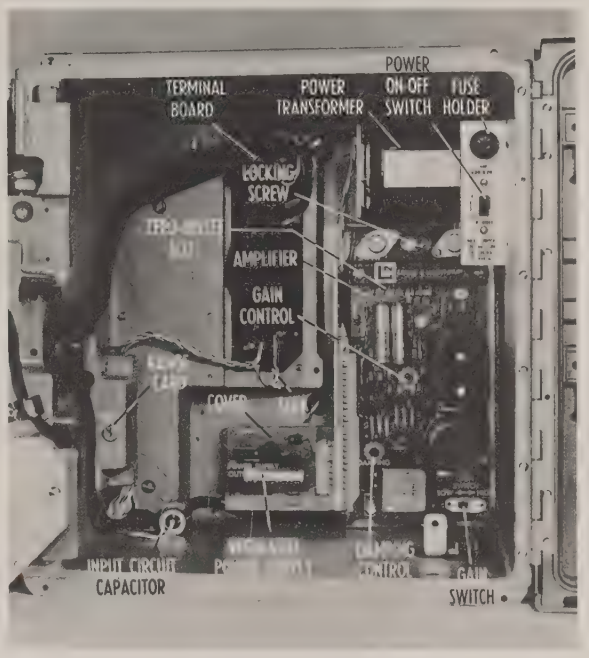
For spans between 20 and 50 mV, repeat the above procedure but with the amplifier gain switch in either the high- or low-gain position, depending upon which setting is better.

At optimum sensitivity hunting disappears or shows as only a slight quiver of the balancing motor worm.

ADJUST DAMPING

All instruments are provided with a damping control, Fig. B11. This is also a screwdriver adjustment located on the amplifier. After instrument start-up and a warm-up of at least two minutes with the instrument measuring the normal input signal, determine the proper setting of this control as outlined in the following paragraph.

Manually rotate the slidewire contact arm to move the measuring pointer several inches from the balance point. Release the contact arm and observe the pointer



E5940

Fig. B11 — Interior of case.

behavior as the instrument balances. Turn the damping control counterclockwise until the pointer overshoots the balance point when this procedure is repeated. Then turn it clockwise until the overshoot just disappears. This setting of the damping control gives the smoothest and fastest balancing action.

ZERO-OFFSET ADJUSTMENT

Instrument measurements may show greater errors on lower millivolt spans than on higher millivolt spans. This may be due to offset voltages generated in the amplifier or injected into the amplifier via external recorder circuitry. A zero-offset adjustment, Fig. B11, is provided on the amplifier to reduce these offset voltages to virtually zero. This adjustment has been set at the factory and ordinarily will not require initial readjustment. However, after a certain period of use, readjustment may be necessary. Refer to Section H.

AMPLIFIER GROUNDING

The amplifier is comprised of an insulated card on which the circuit common is not directly grounded to the case. Instead, the circuit common is factory connected to the negative (—) input terminal inside the case. Also connected to this terminal are the ground filter capacitor and non-grounded input shields, if any, as outlined in Section A, Wiring Connections. This arrangement floats

the amplifier and provides for best rejection of ac common-mode interference because it amounts to a partial guard shield approach for minimizing interference pickup.

Where conditions require grounding of the amplifier circuit common, however, remove the green wire from the negative (—) input terminal and reconnect it under the ground screw located inside the case at the lower left corner of the terminal board. Note that this grounding screw is provided with suitable washer to assure a satisfactory ground. Terminal board mounting screws are no substitute for this grounding point.

PART I — INSTALLATION AND OPERATION . . . . .

Section C — OPERATING ADJUSTMENTS

Depending upon the type of measuring circuit employed, some instruments may require certain adjustments during normal operation. Such adjustments are properly made in accordance with the instructions of this section.

RHEOSTAT ADJUSTMENTS

Speedomax instruments for use with some types of primary elements may incorporate one or more rheostats located at the rear interior of the case, above the range card. Such rheostats are to be adjusted by the user. Brief instructions concerning the adjustments are given below. When more detailed information is required, it will be found in the instructions furnished with the primary element.

RAYOTUBE INSTRUMENTS

The dial-operated rheostat at the rear of the instrument case is known as a Rayotube compensator. After installation of the equipment, this compensator should be adjusted to make the instrument reading agree with the temperature of the Rayotube target as measured by a thermocouple, optical pyrometer or other accurate means. Subsequently, readjustment of the compensator will be required if target conditions change (by accumulation of deposits on target, for example) or if the Rayotube is focused on a different target. No readjustment of the compensator is normally required with target tube installations. Also, the compensator is not to be used to correct for inaccuracies caused by the accumulation of dirt on the Rayotube window—the Rayotube should be kept clean.

To make the compensator adjustment, simply rotate the compensator dial to obtain correct instrument reading.

GAS ANALYSIS INSTRUMENTS

Speedomax instruments for use with 7802 Series thermal conductivity gas analyzers incorporate range and zero rheostats inside the case. After installation of the equipment, these rheostats must be adjusted to make the instrument reading agree with the known composition of samples passing through the analyzer cell. The recommended adjusting procedure is as follows:

(1) Initially, set the range and zero dials to the factory settings which appear on the data card of the analyzer cell cabinet.

(2) Prepare a gas mixture of composition approximately equal to the compensating point, as marked under COMP. on the analyzer data card. Pass this mixture through the analyzer cell assembly and adjust the zero dial until the Speedomax reading corresponds to the composition of the mixture.

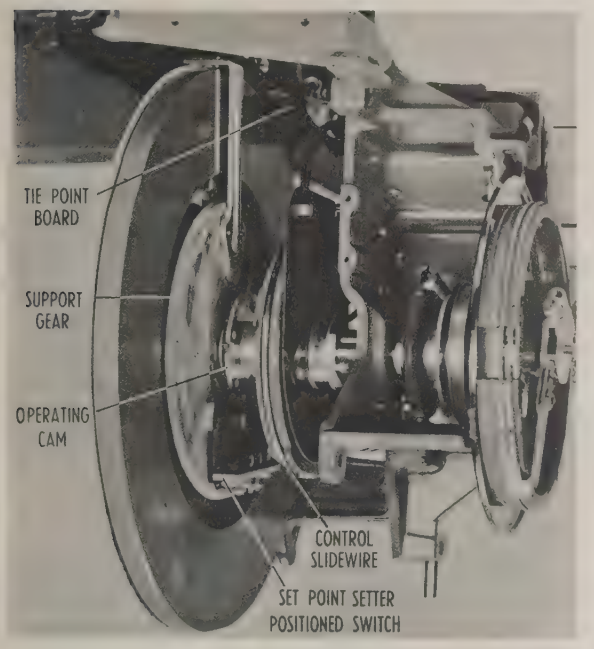
(3) Pass through the cell assembly a gas mixture of composition approximately equal to that end of the analyzer range which is farthest from the compensating point. Adjust the range dial until the Speedomax reading corresponds to the composition of the mixture. If this necessitates moving the range dial by more than two divisions, repeat step (2) and adjust the range dial again. Repeat this procedure until further adjustment of the range dial is unnecessary.

Note: Some gas analyzer applications require modification of the foregoing procedure. Refer to the instructions furnished with the analyzer.

During operation the range and zero settings should be checked and adjusted approximately every two weeks as described above. When repeated adjustments have caused the zero dial to depart from the factory setting by more than 30 divisions, the analyzer measuring cell must be cleaned as outlined in the instructions furnished with the analyzer.

PART I — INSTALLATION AND OPERATION . . . . .

Section D — CONTROL AND ALARM FEATURES



E4520

Fig. D1 — Control assembly.

CONTROL ASSEMBLY

The Speedomax instrument may contain one or more switches arranged to be operated by the rotation of the measuring slidewire shaft. If the instrument is to be used for proportional control, a control slidewire, also rotating with the measuring slidewire shaft, is provided. The control slidewire and switches, together with associated cams, setting device, etc., form a complete assembly more or less similar to that shown in Fig. D1. Such an arrangement of components is called a *control assembly*. This designation applies even when the assembly performs some function other than control.

Any one of several combinations of switches and slidewires may be provided. The principal uses of such arrangements are:

Alarms—Switches can be connected to external circuitry to actuate alarms or other safety devices when certain preselected instrument readings are attained.

Simple Control—One or more switches can be used to turn a final control device on and off at predetermined readings and thereby control the variable being measured. This "on-off" or two-position method of control is described more fully in Section M.

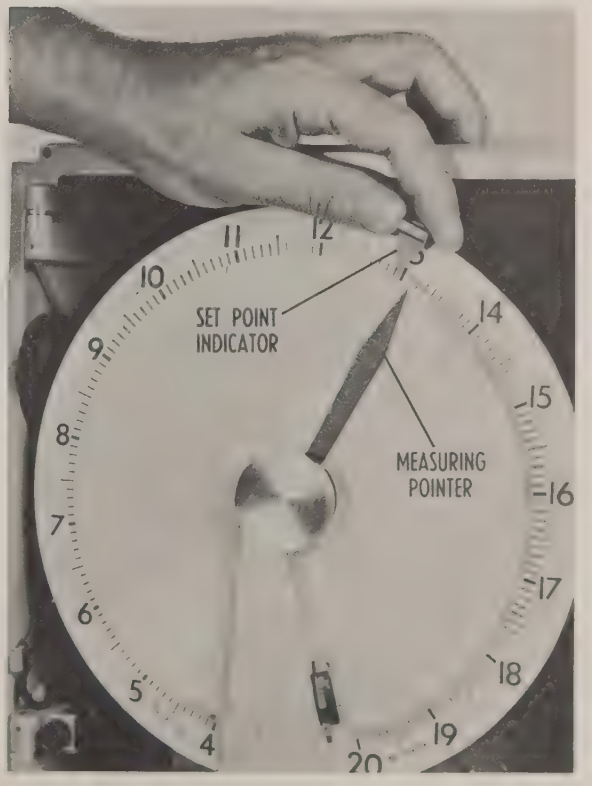
Proportional Type Control—When proportional control is furnished, a slidewire of the type shown in Fig. D1 is provided. This slidewire is connected into the bridge circuit of a separate controller which operates a final control element (through appropriate circuits) to maintain the measured variable at a preset value. Usually the measuring instrument and controller form a "package" complete with all necessary internal wiring. Refer to the separate manual for the controller.

Although the control assembly is *mechanically* part of the Speedomax instrument, its wiring is entirely separate from that of the measuring circuit and balancing system. Therefore, the instrument can be placed in service, for measuring purposes, before any adjustments to the control assembly are made, and before control assembly wiring is installed.

SET POINT SETTER

The control assembly consists of two principal parts —(1) an assembly of control slidewire and operating cams which rotate with the slidewire shaft, and (2) the corresponding sliding contact and switches, mounted on a support gear which is linked to the set point indicator. Both of these parts are equipped with adjustable clutches to permit the proper control assembly setting to be made and retained.

The support gear, and hence the switches and slidewire contact, can be conveniently set to any desired position from the front of the instrument. As shown in Figs. D2 and D3, this is accomplished directly on the Model R instrument by moving the set point indicator itself to the desired setting, while on the Model S, oper-



E4521

Fig. D2 — Operation of the Model R set point setter.

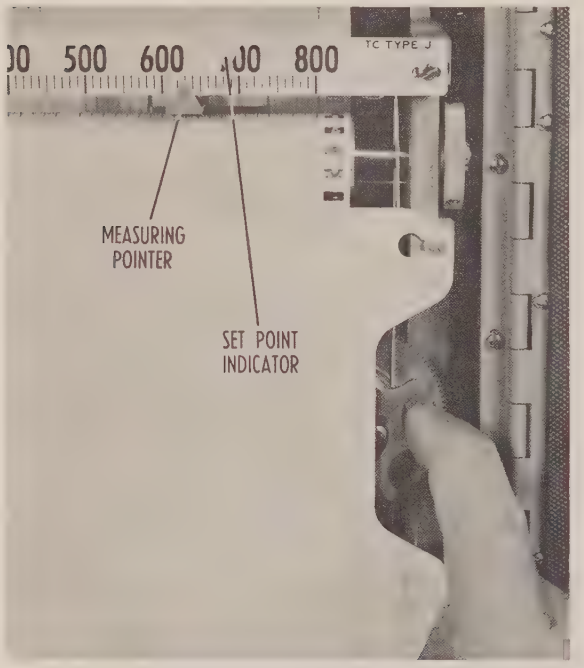


Fig. D3 — Operation of the Model S set point setter.

ation is by means of a set point setter. In either case, the set point indicator shows the setting of the control assembly components.

After proper initial adjustment of its cam, each switch will be operated automatically whenever the instrument reading (measuring pointer) bears a certain predetermined relationship to the set point setting (set point indicator). Similarly, the position of the sliding contact on the control slidewire depends upon the relationship between the two pointer positions. Thus the set point setter provides convenient selection of setter positioned switch and slidewire operating points.

STATIONARY SWITCHES

Some instruments have cam-operated switches mounted directly on the hinged casting. Such stationary switches are independent of the set point setter and the set point indicator. Each stationary switch operates at a particular value of instrument reading which is determined by the setting of its operating cam.

CONTROL ASSEMBLY WIRING DIAGRAM

The internal wiring to the control assembly is not shown on the same diagram as are the measuring and motor circuits. Instead, a separate control assembly wiring diagram is furnished. The circuit of a typical control assembly wiring arrangement is shown in Fig. D4.

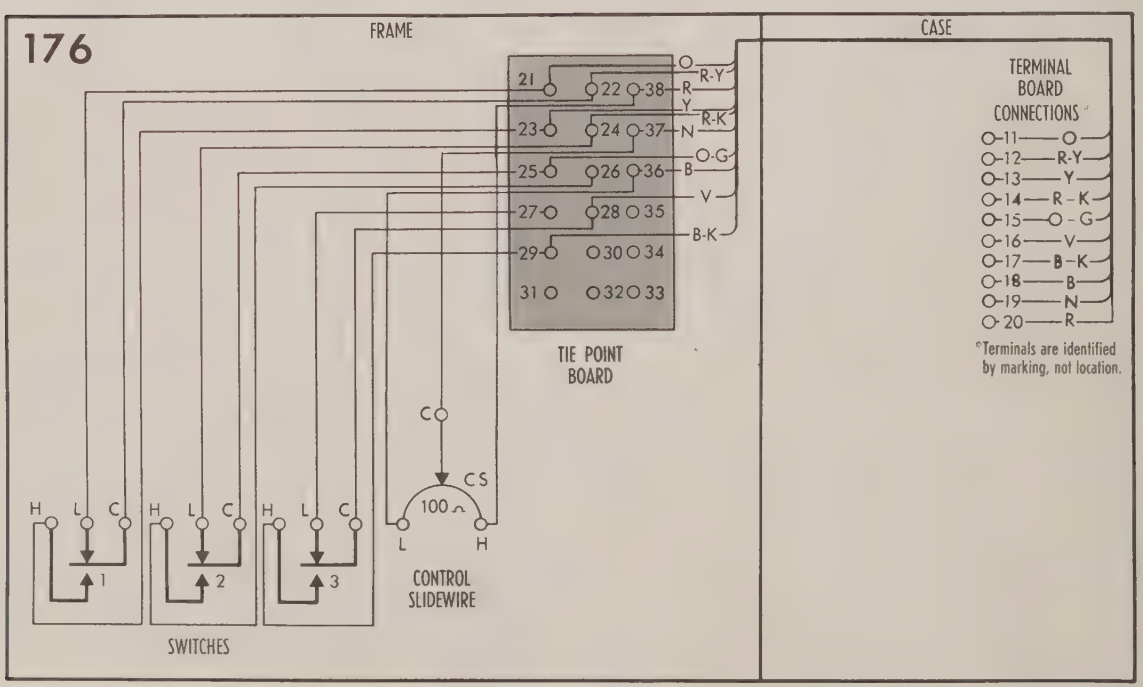


Fig. D4 — Internal control assembly wiring arrangement for three switches and a control slidewire.

To identify the correct control assembly wiring diagram for a particular instrument, look at the instrument catalog number which is given on the nameplate inside the instrument case. This is a coded number, and its *third element* represents the internal control assembly wiring arrangement. The circuit of this arrangement is shown in the particular wiring diagram (Fig. D4) which is marked with the same number.

Example: If the instrument catalog number is:
200-101-176-0001-6-024-000

then the third element—176—is the control assembly wiring number. Fig. D4 shows the control assembly wiring for the instrument.

In connection with the control assembly wiring diagrams, note the following:

(1) When more than one switch is present, the switches are numbered on the diagram. Numbering is in order of switch position, starting with No. 1 for the switch nearest the support gear.

(2) The terminals of switches are designated H, L, and C, standing for high, low and common, respectively. Definitions of high and low contacts are as follows:

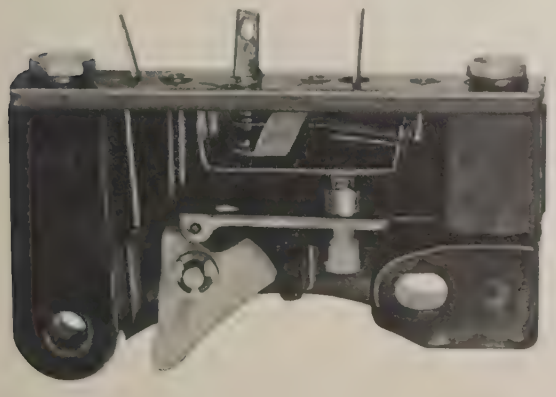
A *high* contact is one which is closed when the measuring pointer is between the set point of that contact and the *right* end of the scale.

A *low* contact is one which is closed when the measuring pointer is between the set point of that contact and the *left* end of the scale.

(3) When an auxiliary relay is provided as part of the control circuit, this relay is located in the rear of the instrument case, above the range card.

SWITCH CHARACTERISTICS

Fig. D5 shows the standard type of switch used in the instrument. This is an spdt snap-action switch which is actuated by an operating cam. The switch has no stable open position—for any position of its cam, either the high or the low contact will be closed.



E4523

Fig. D5 — Switch.

The rated current interrupting capacity of a switch is as follows:

AC loads (noninductive)	1.0 ampere at 120 V ac 0.5 ampere at 240 V ac
DC loads (noninductive)	0.1 ampere at 120 V dc 0.05 ampere at 240 V dc

Inductive loads—No rating can be given since capacity depends upon characteristics of the load and associated circuits.

PRELIMINARY CONTROL ASSEMBLY ADJUSTMENTS

Checking Model S Indicator Position — Before proceeding with other adjustments, turn the set point setter first in one direction and then the other. The set point indicator should be able to move over the entire scale. If if cannot, loosen the indicator clamp screw and turn the set point setter clockwise until the mechanical stop is reached. Then move the indicator until it is about 1/16″ above the first line of the scale, and clamp it to its drive cord.

Switch Adjustment — When adjusting switches, connect an ohmmeter to the appropriate tie point terminals (see Fig. D1) to determine when switching action occurs. Turn off all power to the instrument before making adjustments. The instructions given here apply to each switch of the control assembly.

Actual adjustment of an operating cam is made with a specially-designed wrench supplied with the instrument. Fig. D6 illustrates the use of this tool.

E4524

Fig. D6 — Use of wrench to adjust operating cams.

If the switch is set point setter actuated, first bring the set point indicator to a main division near the center of the scale. Then manually rotate the slidewire contact arm to bring the measuring pointer to the reading at which switch operation is desired for the set point indicator setting which has been selected. While holding the arm in this position, turn the appropriate operating cam on its sleeve to the point where switching action occurs.

Adjustment of a stationary switch is as just described except that the set point indicator setting is immaterial. Simply set the measuring pointer to the scale reading at which the switch is to operate, and adjust its cam as instructed above.

Control Slidewire Adjustment — For the proper adjustment of the control slidewire, refer to the manual for the controller. Usually, the control slidewire contact must be at, or slightly above, the center of the slidewire when the measuring pointer and set point indicator are in line. Rotate the control slidewire on its sleeve until this condition is obtained. While making the adjustment, use an ohmmeter to measure the position of the sliding contact on the slidewire.

CONTROL ASSEMBLY WIRING ARRANGEMENTS

Fig. D4 is a diagram of a frequently used control assembly wiring arrangement. Since many different types of these arrangements are available—too many to be covered in a single manual—the control assembly wiring arrangement for an instrument is provided on a diagram supplied with that instrument. Wiring connections to the user's equipment should be made in accordance with that diagram. Each diagram shows only the external connections to the instrument terminal board, and specifies the various internal arrangements with which the external circuitry is suitable. It may be that for some combinations, not all of the switches in the instrument are used. If desired, such switches can be employed to operate alarms, signals, etc.

For a discussion of two types of control—two-position single point and two-position differential gap, refer to Section M.

PART I — INSTALLATION AND OPERATION . . . . .

Section E — ROUTINE MAINTENANCE

This section covers the few routine maintenance procedures required during normal operation of the instrument.

CARE OF PEN AND INK SUPPLY

Model R Recorder

Refilling Pen—It is recommended that the pen be refilled when the ink level falls within ¼″ of the bottom of the reservoir. In no case should the pen be allowed to run completely dry, since this necessitates repriming and may also permit the ink to dry inside the capillary with consequent clogging of the pen.

The refilling procedure is identical to the initial filling procedure, except that priming is not required.

Failure of Pen—If the pen stops inking while the reservoir still contains sufficient ink, it may be possible to start the ink flow by one of the following methods:

—Moisten a finger and draw it across the penpoint.

—Repeat the priming procedure.

If neither of these methods is successful, insert one of the fine wires (supplied with the instrument accessories) in the back (reservoir end) of the pen capillary and push it through the capillary to clean out any particle clogging it. The pen must be primed when the capillary is replaced.

In extreme cases, where the ink still does not flow, remove the clogged pen and install a new one. Place the clogged pen in alcohol or hot water for a short time and then insert a cleaning wire as previously directed. Fill the ink dropper with alcohol or hot water, fit its spout over the penpoint, and force the fluid through the capillary. Allow both the pen and dropper to dry thoroughly before using. If ink has been allowed to dry in the pen, the reservoir should also be cleaned with hot water before further use.

Model S Recorder

Refilling Ink Bottle—It is recommended that the ink bottle be refilled or replaced when the ink level falls within ¼″ of the bottom of the ink bottle. The ink supply should not be allowed to run completely dry since this necessitates repriming, and may also permit ink to dry inside the capillary system with consequent clogging of the system.

To refill or replace the ink bottle, remove the bottle from the bottle holder, Fig. B6. When doing this, it is not necessary to disconnect the plastic capillary tube from the metal capillary tube. Unscrew the cap, withdraw the vent and metal capillary tubes, Fig. B5, from the bottle, and let the cap assembly with attached plastic capillary tube rest on the bottle holder. Then refill the ink bottle or replace it with a new bottle of ink. When refilling, observe that the bottle is to be filled only to the line marked FILL TO LINE. Replace the cap assembly, leaving the cap somewhat loose. Then replace the bottle in the bottle holder. Make sure that the key in the base of the bottle is seated in the keyway in the bottle holder. Then, while holding the metal capillary tube so that it points towards the capillary slot, Fig. B6, tighten the cap securely.

Failure of Pen—If the pen stops inking while the bottle contains sufficient ink, it may be possible to start the ink flow by one of the following methods:

—Moisten a finger and draw it across the penpoint.

—Repeat the priming procedure.

To insure that no foreign particles remain in the capillary system, continue forcing ink through the pen to wash out any foreign particles. When the system is clean, the ink will squirt out of the pen in a fine stream.

Note: If during the priming procedure the ink is drawn back into the capillary system when pressure on the ink bottle is released, then the vent tube is clogged. Clean out any particles clogging the vent tube by inserting one of the fine wires (pen cleaners) supplied with the instrument accessories, into the top of the vent tube; push the pen cleaner through the tube several times to dislodge and clean out the obstructing particles.

If neither of the preceding methods achieves the desired result, disconnect the pen, Fig. B7, from the auxiliary reservoir. Then insert a clean, unburred pen cleaner into the auxiliary reservoir end of the pen assembly. Push the cleaner through the pen several times to dislodge and clean out any particles clogging the pen. Prime the pen after reconnecting it to the auxiliary reservoir.

If the pen cleaner cannot be pushed through the pen, remove the clogged pen and install a new one. Place the clogged pen in alcohol or hot water for a short time. Then dislodge and clean out the particles clogging the pen with a clean, unburred pen cleaner as directed in the preceding paragraph. Remove any fluid from the pen and allow the pen to dry thoroughly before using it again. Drying of the pen can be facilitated by air purging.

Caution: To prevent damage to the sapphire pen nib, make sure that the wire pen cleaner is always removed in a straight line with respect to the hole in the pen nib.

Replacement of Plastic Capillary—It is recommended that the plastic capillary tube be replaced every three years. However, should extreme operating conditions cause the tube to lose its elasticity, replace the tube whenever this occurs. Check the elasticity of the tube every three to six months. It is also recommended that the extra-flexible tube, reservoir, and reservoir connector be replaced whenever the plastic capillary tube is replaced. A new plastic capillary tube, extra-flexible tube, reservoir, reservoir connector, and pen assembly are contained in the 124606 Accessory Kit for field installation in the recorder. The kit is available from the Leeds & Northrup Company.

To replace the plastic capillary tube, extra-flexible tube, and reservoir connector, proceed as follows:

(1) Remove the chart from the instrument to provide additional room for working, thereby facilitating the replacement procedure.

(2) Remove the pen assembly, Fig. B7, from the pen carriage. Then allow it to rest on the carriage in such a manner that the penpoint will not be damaged.

(3) Draw the ink from the capillary system back into the bottle by reversing the priming procedure. That is, first squeeze the bottle, next close the vent tube, and then slowly release pressure on the bottle. It may be necessary to repeat this reverse priming procedure several times to draw most of the ink out of the auxiliary reservoir and all of the ink out of the capillary system.

(4) Disconnect the auxiliary reservoir from the reservoir connector and then remove the pen and reservoir from the pen carriage. Disconnect the pen from the reservoir.

(5) Remove the Truarc E-ring, Fig. B6, from the hinge side of the capillary shaft. Then remove the shaft.

(6) Disconnect the plastic capillary tube from the metal capillary tube at the ink bottle.

(7) Remove the capillary clamp, Fig. B7, from the pen carriage, taking care not to lose the screw and nutplate.

(8) Remove the plastic capillary tube and metal tubing connector from the clamp. Then remove the plastic capillary tube from the metal tubing connector, the metal tubing connector from the extra-flexible tube, and the extra-flexible tube from the reservoir connector.

(9) Remove the capillary clamp, Fig. E1, from the hinge side of the hinged casting, taking care not to lose the screw or nutplate. Then remove the plastic capillary tube from the clamp.

Caution: When installing the new plastic capillary tube, take care not to crimp the tube as this may damage it.

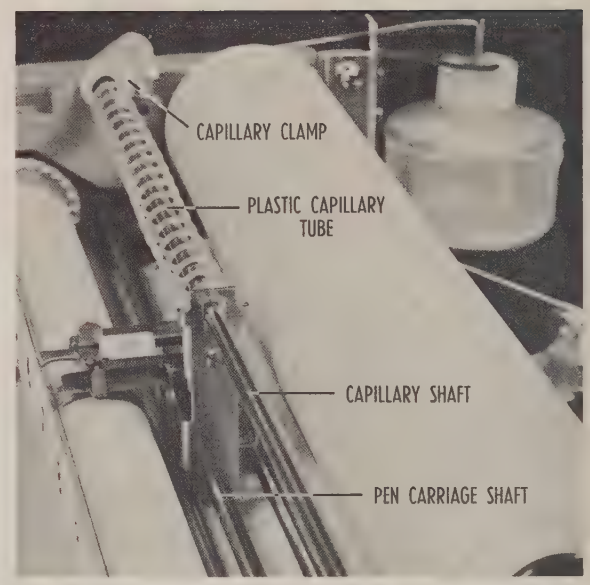
(10) Insert the swaged end of the metal tubing connector into the short uncoiled end of the new plastic capillary tube. Insert the other end of the connector into the new extra-flexible tube. Fasten the short uncoiled end of the plastic capillary tube to one of the capillary clamps in the following manner.

(a) Insert the first coil of the tube into the notch of the clamp as shown in Fig. E2.

(b) Fit the coil in the groove in the clamp so that the straight portion of the tube is in the position shown in Fig. E3. Press the straight portion of the tube into the straight groove of the clamp to complete this procedure.

(11) Fasten the last coil of the tube to the other clamp in a similar manner. Then fasten this clamp to the hinge side of the hinged casting. Use a nutplate and screw to secure the tube in the clamp and the clamp to the hinged casting.

(12) Fasten the other clamp to the pen carriage. Use the other nutplate and screw to secure the tube and *swaged portion only* of the metal tubing connector in the clamp and the clamp to the pen carriage. Make sure that the metal tubing connector is mounted as shown in Fig. B7.



E5243

Fig. E1 — Top view of hinged casting of Model S recorder, showing plastic capillary tube and pen carriage.

(13) Remount the capillary shaft, inserting it through the coils of the new plastic capillary tube. Replace the Truarc E-ring to secure the shaft in place.

(14) Connect the free end of the tube to the metal capillary tube at the ink bottle. Position this portion of the tube so that it will not touch the chart or the recorder case when the hinged casting is swung back into the case and locked in place. See Figs. E1 and B6.

(15) Moisten the capillary end of a new pen or the previously removed one with a dampened cloth, paper towel, or paper tissue. Then insert the moistened end of the pen into the offset end of the auxiliary reservoir, Fig. B7, so that the offset fits over the top of the pen. Force fit either end of the reservoir connector into the other end of the reservoir. Moisten the free end of the reservoir connector and then connect it to the free end of the extra-flexible tube. Note that the reservoir connector may vary in shape from that shown in Fig. B7.

(16) Prime the system, install the pen assembly in the pen carriage, and reinstall the chart as directed in Section B, to complete this replacement procedure.

CLEANING AND LUBRICATING

Since the instrument is a continuously operating mechanism, occasional cleaning and lubricating are required. The schedule given below should be followed under normal conditions of use. Where the instrument location is very dusty, more frequent cleaning and lubricating may be necessary.

E4783

Fig. E2 — Insertion of first coil of plastic capillary tube into notch of capillary clamp.

E4784

Fig. E3 — Positioning of straight portion of plastic capillary tube in straight groove of capillary clamp.

Cleaning—The following cleaning operation should be performed every two months.

Measuring Slidewire—Rub a clean cloth, moistened with a commercially-available contact cleaner, over the contacting surfaces of the measuring slidewire. Then wipe dry with a clean cloth or tissue. ***Do not apply any lubricant to the measuring slidewire.***

Pen Carriage And Capillary Shafts, Model S Instruments—Swing out the hinged casting to gain access to the pen carriage and capillary shafts, Fig. E1. Place a small quantity of oil on a cloth and rub the shafts with the cloth until they are clean. Leave a thin film of oil on the shafts for lubrication. A screwdriver slot at one end of the pen carriage shaft permits this shaft to be unscrewed a half turn for cleaning of its underside. This shaft can also be removed entirely for cleaning. Be sure to replace and tighten the shaft properly after cleaning. If the shaft has been removed, check the pen lineup as instructed in Section H and readjust the lineup, if necessary.

Clutch and Gear Assembly—The clutch and gear assembly, Fig. F10, should be removed and cleaned every six months. Turn the instrument off and remove the chart and chart platen. Remove the screw from the center of the clutch and gear assembly, Fig. F10—this screw has a left-hand thread—and lift out the assembly.

Use the Standard Pliers No. 2 and remove the retaining ring from the end of the assembly. Lift off the bronze washer, the large friction disk and the smaller friction washer. Thoroughly clean the friction disk and friction washer and reassemble the parts. In doing this, see that the notch in the friction washer lines up with the small hole in the part to which the gear is attached. Keep this friction washer in this position while replacing the friction disk, bronze washer and retaining ring.

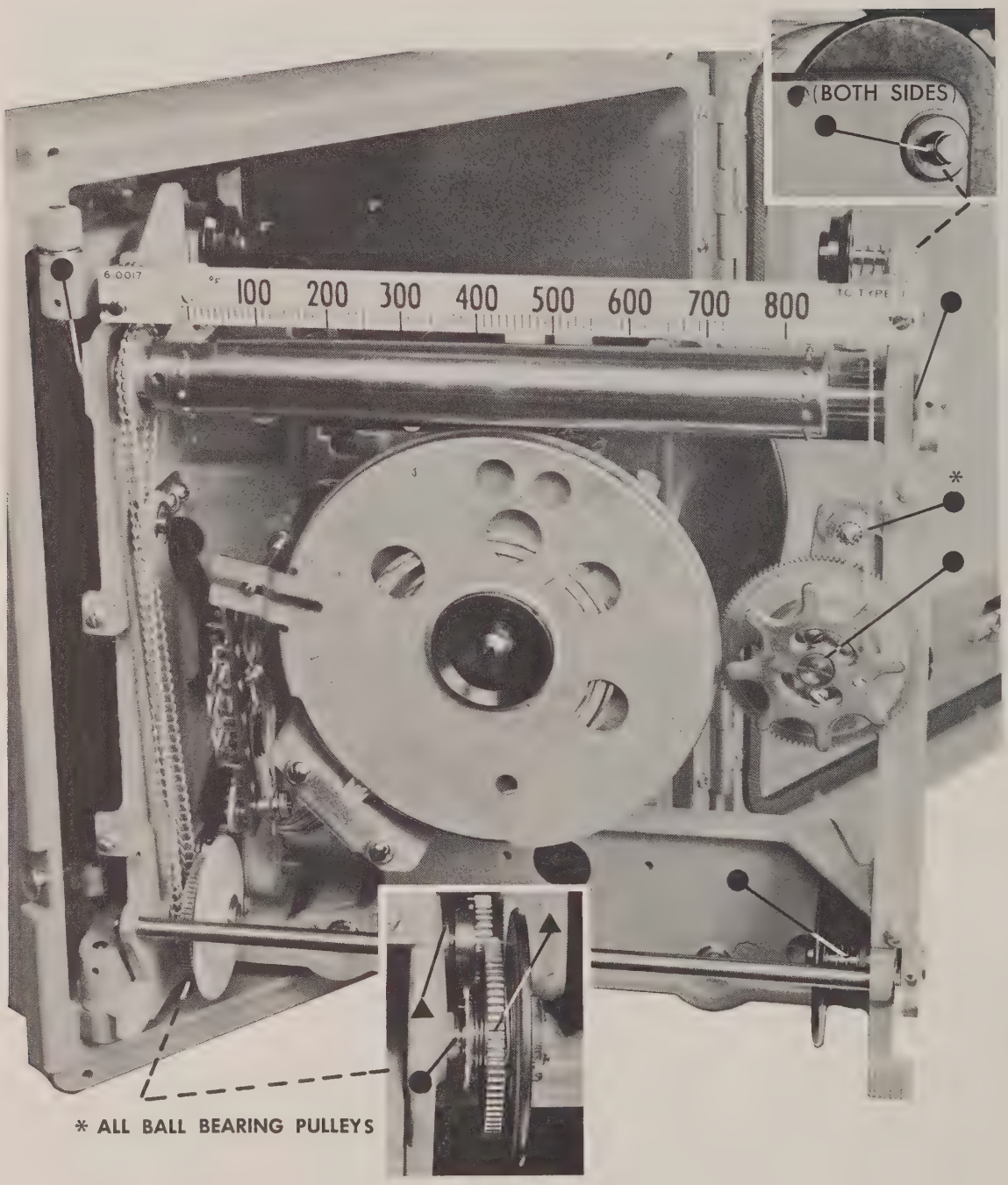
Replace the assembly and hold it in place with the screw. Note that the gears mesh properly and see that the drive chain is fitted back of the guide wheel on the frame casting.

Pen Bracket, Model R Instruments—The hub on this pen bracket and the end of the slidewire shaft on which this hub fits should be cleaned and greased every six months. To do this pull the bracket forward and down as far as it will go. Then remove the ball and spring from the hub of the bracket. Thoroughly clean the spring and ball and wipe old grease from the hub. Coat the spring and ball with Beacon 325 grease or equivalent and replace, making sure the ball is free in the hub.

Clean the end of the shaft on which the hub fits, and coat the end of the shaft with grease.

Lubrication—Use a good grade of medium weight, nondetergent oil, e.g., L&N recorder oil, to lubricate the points indicated in Fig. E4. Place on only one or two drops of oil at a time and wipe off any excess. On the ball bearing pulleys, be particularly careful that no oil gets on the drive cord(s) as this may accelerate wear of the cord(s).

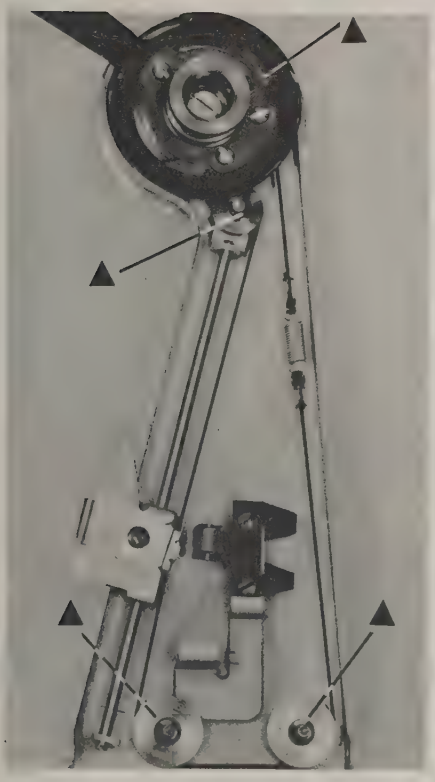
A more suitable method of lubricating exposed parts, such as gear teeth, cams, etc., is to use a #3 or #4 artist's brush. Dip the brush in oil, remove the excess by wiping across the lip of the container once, and then apply the oil-filled brush to the exposed part(s).



FRONT STRUCTURE
MODEL S INSTRUMENTS

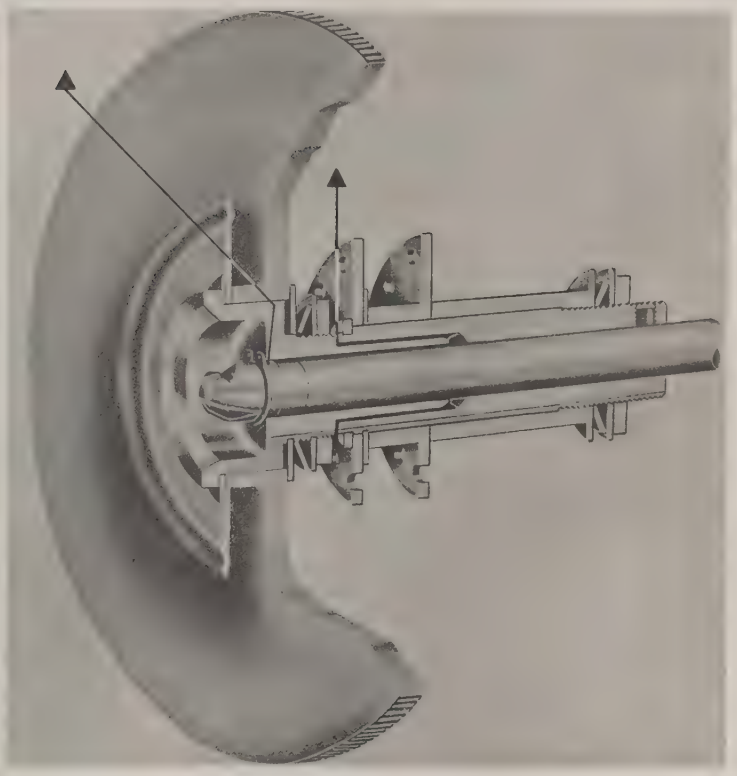
E4526

Fig. E4 — Lubrication schedule.



E4527

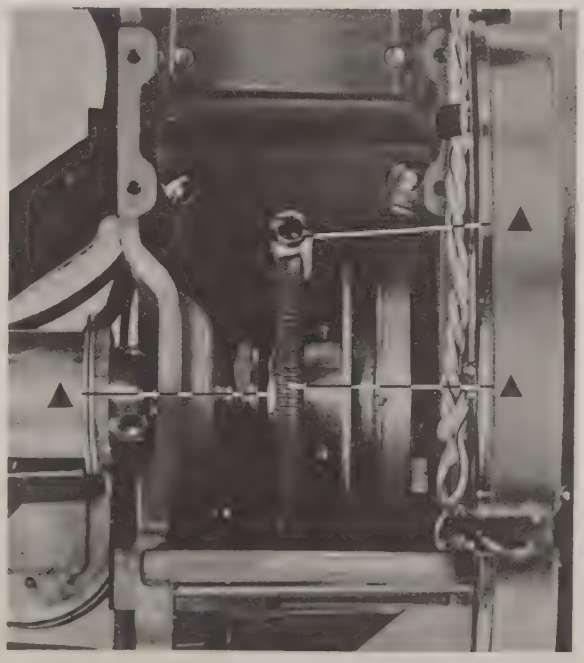
PEN BRACKET
MODEL R INSTRUMENTS



CE4528

CONTROL ASSEMBLY
ALL INSTRUMENTS HAVING CONTROL

MOTOR WORM
AND WORM GEAR
AND
WORM GEAR CLUTCH



E4529A

▲ **LUBRICATE EVERY 2 MONTHS**
● **LUBRICATE EVERY 6 MONTHS**

Fig. E4 — concluded.

RECORDER INKS

Recorder inks come in two types: slow drying and fast drying (formerly designated as "annual" ink and water-base ink, respectively). Generally, for chart speeds below 10 inches per hour use slow-drying ink and for chart speeds above 10 inches per hour use fast-drying ink. Other factors that may affect ink selection are pen activity, recorder speed of response, and primary element speed of response.

The slow-drying ink does not air dry, i.e., evaporate, readily. Neither does it appreciably wet the paper. Thus, if too much is deposited on the paper, it may remain wet for some time. To assure the proper amount, the ink level in the bottle must be kept below the level of the pen tip. This may require keeping the ink bottle only about half full.

Besides being used with slow chart speeds, this ink is also suitable for use with faster chart speeds when there is very little pen activity, or where the activity is a slow oscillating type. It can be used on most records with balancing speeds of two seconds or slower, or when the primary element has a slow response.

For chart speeds above 10 inches per hour, use the fast-drying type which dries quickly. It can't be used with slower chart speeds where the pen remains for longer periods of time, or with any combination of chart speed and pen activity that cause the pen to track over wet chart, for then the pen is apt to tear paper fibers loose and clog. Therefore, this ink performs best with fast chart speeds, a balancing time of one second or less, and where the pen makes wide excursions across the chart.

For Speedomax H Model S recorders, both types of ink described above are available. The user must select the one best suited to his needs, based on the preceding discussion. For the Model R recorder, only the former type is recommended because of the nature of round chart recordings, which are generally at slow speeds. See Table E1.

Because no ink can compensate for improper pen alignment or inadequate priming, make sure that:

(1) No air gets into the pen system through loose connections or poor priming techniques. Proper priming (purging of air) is especially important in capillary pen systems. Many failures that are attributed to pen clogging are actually caused by air bubbles. Force enough ink through the system to assure that all the air has been forced out. Because of the difference in viscosity of the two types of ink, the fast-drying ink can be forced through the system with much greater ease than can the slow-drying ink.

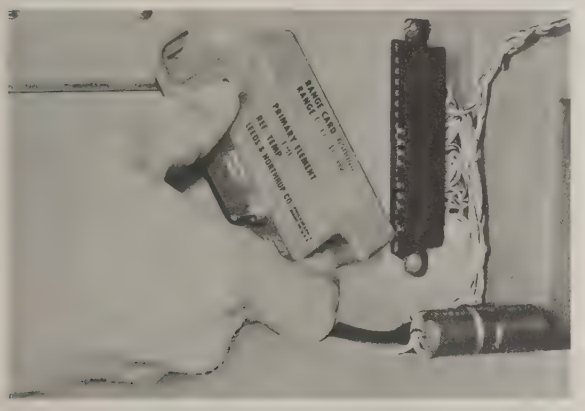
(2) Pen pressure should be as light as possible. Generally, high-speed applications that use fast-drying ink may require slightly higher pressures than slow-speed applications that use the slow-drying ink.

(3) The flat of the penpoint should be flat against the chart roll, i.e., 90° to the surface of the chart roll.

TABLE E1 — L&N RECORDER INKS

Slow-Drying Type				
Bottle Size	L&N Part Number Red	Black	Blue	Green
2 oz	125133	125055	125143	125147
8 oz	125135	125064	125144	125148
16 oz	125149	125053	125141	125142
Fast-Drying Type				
Bottle Size	Red	Black	Blue	Green
2 oz	125051	125131	125113	125114
8 oz	125060	125150	125151	125145
16 oz	125045	125104	125124	125146

Section F — REMOVAL AND INSTALLATION OF PARTS



E4531

Fig. F1 — Removing range card.

In servicing the instrument, it may be necessary to remove one or more parts. This section describes and illustrates such partial disassembly operations and also indicates, where necessary, the replacement or installation of the parts. In all cases where several steps are required to effect a removal or replacement, these steps should be followed *in the order given.* Turn off all power to the instrument until completion of the required operations unless otherwise noted.

TOOLS

A special control wrench and a set of Allen wrenches are supplied with the instrument. With the single exception mentioned below, no other special tools are needed for working on the instrument.

A number of Waldes Truarc retaining rings are used in assembling the parts. To facilitate removal or installation of these devices, the following tools, designed specifically for the purpose, should be available:

Alternate Field Pliers No. 0 — for small external retaining rings (No. 12 to No. 23).
Standard Pliers No. 2 — for all other external rings in the instrument.
Standard Pliers No. 1 — for internal ring (used only to retain slidewire shaft bearings in hinged casting).

If not otherwise available, these pliers may be ordered from Waldes Kohinoor, Inc., Long Island City, New York 10001.

RANGE CARD

Electrical connections to the range card are made through a plug-in connector. Thermocouple range cards, in addition, include extension wires which connect to the input terminals on the front (back side) of the terminal board. A slot in the bottom of the terminal board permits the extension wires to be brought through for connection. See Fig. B11.

To remove the range card initially, loosen the two retaining screws and pull the card forward. See Fig. F1. On thermocouple types, disconnect the extension wires from the terminal board.

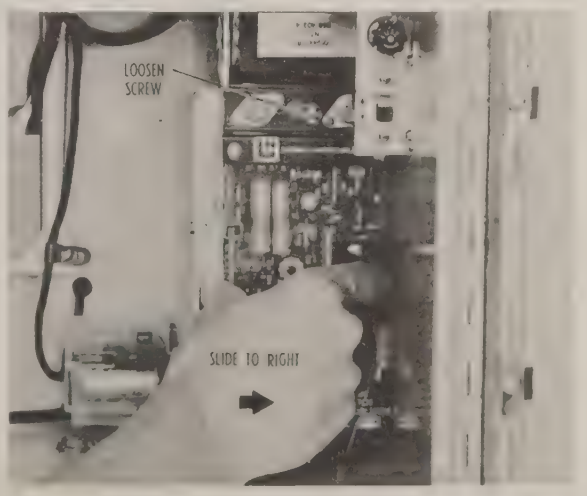
To replace the range card or install a new one, reverse the above procedure. Because of the type of connector used, the two mounting screws do not require tightening unless additional clamping action is necessary, e.g., because of excessive vibration, etc. Observe polarity when connecting extension wires for thermocouple types. For emf instruments involving a change in the range card emf span, check Section L, EMF Failsafe, for possible change of the failsafe resistance value.

AMPLIFIER

The amplifier is a plug-in type, secured in position with a nylon screw, and, on some models, a knurled stop screw. A clear plastic cover protects components on the card and provides for convenient handling.

Through the hole in the cover, insert a screwdriver and loosen the nylon screw. Loosen the nut on the stop screw if present, and turn the stop screw in to provide space for withdrawing the amplifier from its connector. Then holding the unit as shown in Fig. F2, slide it to the right and withdraw it. Do not use the input transformer (which projects above the cover) as a means of handling the amplifier. After removal, the cover may be taken off by backing out the four screws which hold it in position. Note that nylon screws are used at the top and metal screws at the bottom. Observe proper location as indicated to avoid possible contact with hazardous voltages.

Before replacing the amplifier, make sure that the cover is in place. Then slide the unit into the connector until firmly seated. Back out the stop screw until its head touches the case and tighten in place with the lock nut. Finally, retighten the nylon screw.



E5941

Fig. F2 — Removing amplifier.

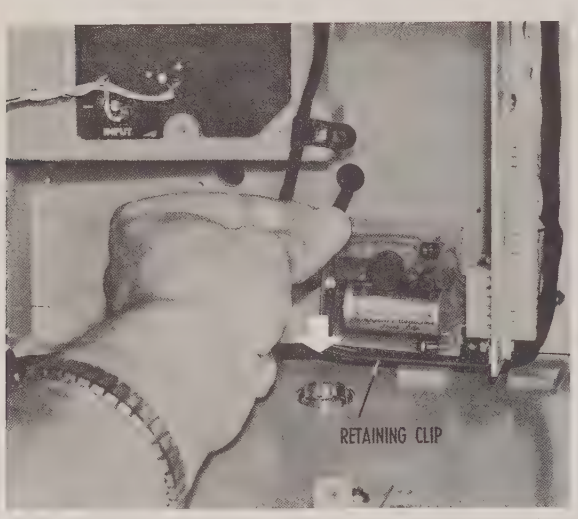


Fig. F3 — Removing regulated power supply. Push down retaining clip while pulling out card as shown.

REGULATED POWER SUPPLY

The regulated power supply, also a plug-in type, mounts on the left side of the amplifier. An extension of the amplifier cover serves to protect this unit. See Fig. B11.

To remove the power supply, first take out the amplifier as instructed above. Then depresss the retaining clip, Fig. F3, and slide the unit to the left, holding it by the card as illustrated in Fig. F3. Avoid exerting undue forces on any of the electronic components.

Replace by depressing the retaining clip and pushing in on the card until the retaining clip snaps in place. Then replace the amplifier and lock in place with the retaining screw.

DRIVE CORD REPLACEMENT

Model R Pen Drive Cord — The pen drive cord for the round chart recorder is supplied precut to the proper length and with a spring connecting its two parts. The cord can be installed easily when the pen is removed and the pen bracket swung out. It is not necessary to remove the bracket from the instrument.

Remove all pieces of the old cord and install the new one according to the sequence of steps given in Fig. F4. After the cord is installed, clamp the pen carriage loosely to it. Similarly, the pointer should be replaced and its clamp plate only partially tightened. Then adjust the scale, pointer, and pen lineup as instructed in Section H.

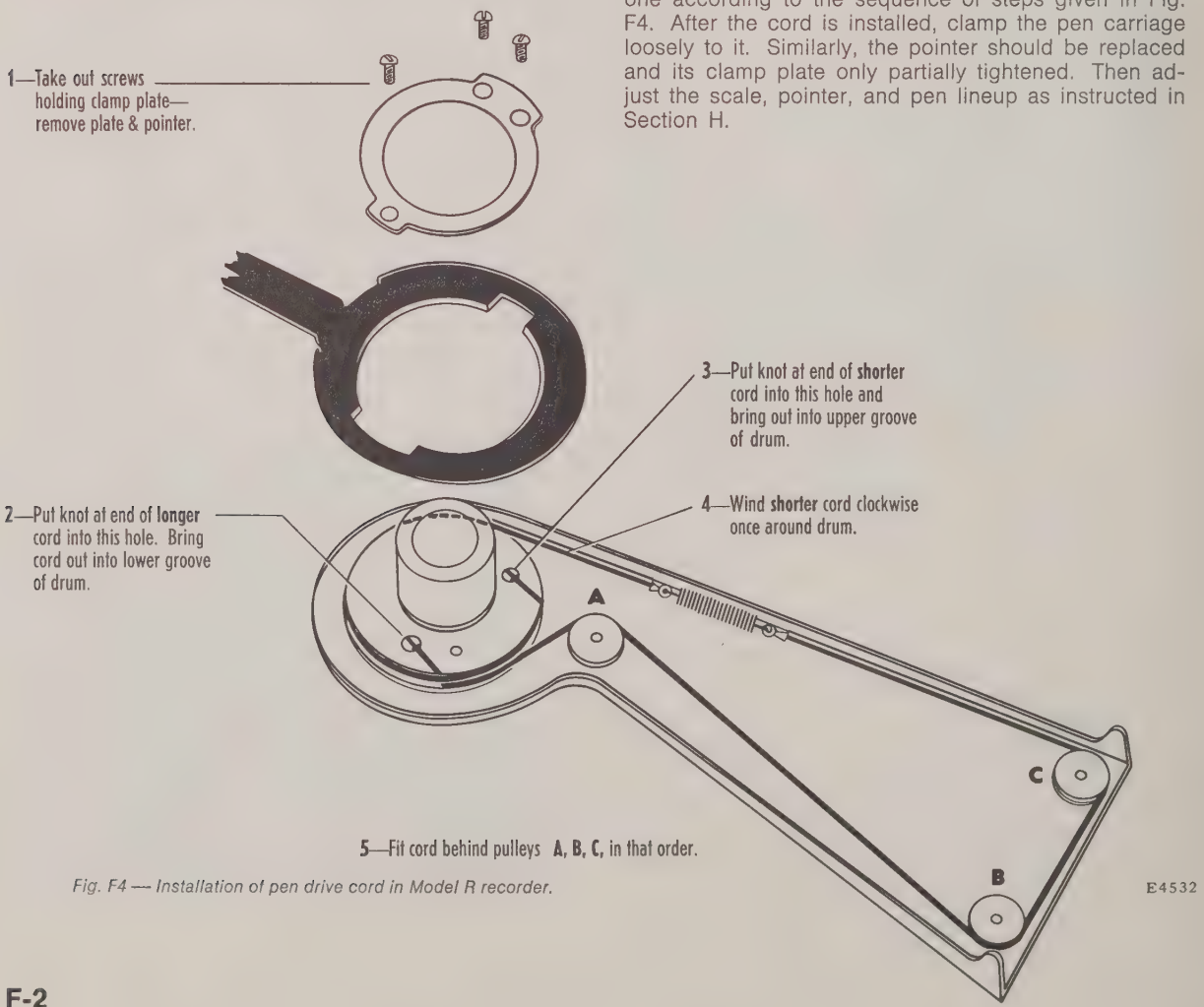
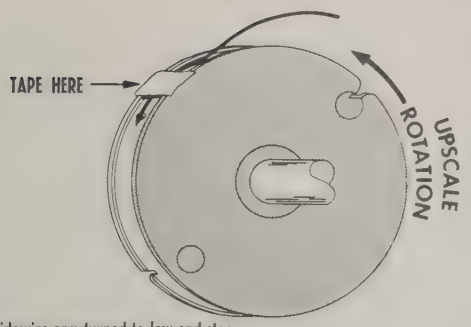
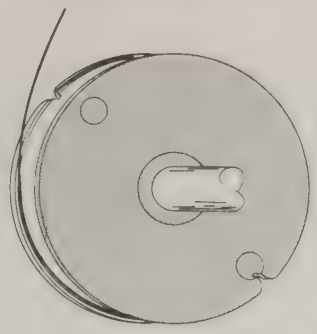

1—Take out screws holding clamp plate— remove plate & pointer.
2—Put knot at end of longer cord into this hole. Bring cord out into lower groove of drum.
3—Put knot at end of shorter cord into this hole and bring out into upper groove of drum.
4—Wind shorter cord clockwise once around drum.
5—Fit cord behind pulleys A, B, C, in that order.
A
B
C
E4532

Fig. F4 — Installation of pen drive cord in Model R recorder.

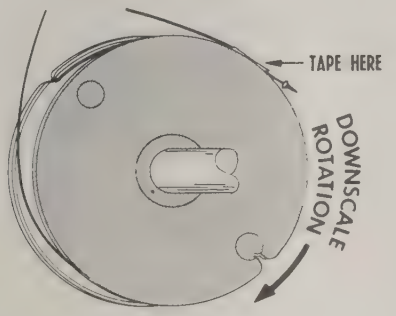


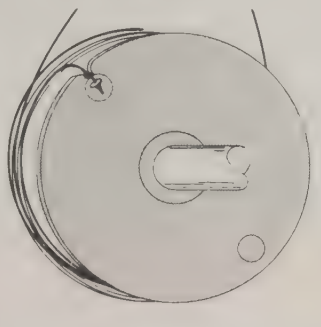
1—With slidewire arm turned to low-end stop, tape one end of cord to large pulley on measuring slidewire shaft. Now rotate measuring slidewire shaft in upscale direction to carry end of cord down around pulley.



2—Detach tape and place bead in front slot of pulley (i.e., slot nearest chart assembly).

4—Detach tape and place bead in rear slot of pulley shown.

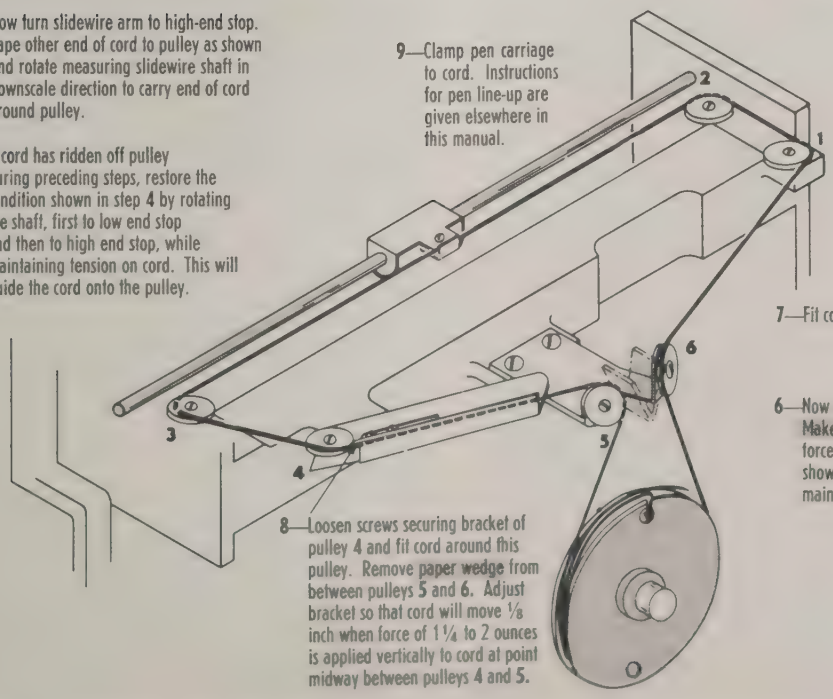




3—Now turn slidewire arm to high-end stop. Tape other end of cord to pulley as shown and rotate measuring slidewire shaft in downscale direction to carry end of cord around pulley.

5—If cord has ridden off pulley during preceding steps, restore the condition shown in step 4 by rotating the shaft, first to low end stop and then to high end stop, while maintaining tension on cord. This will guide the cord onto the pulley.

9—Clamp pen carriage to cord. Instructions for pen line-up are given elsewhere in this manual.



7—Fit cord around pulleys 1, 2, 3.

6—Now fit cord over pulleys 5 and 6. Make a wedge of folded paper and force it between the pulleys as shown to hold the cord taut on the main pulley.

8—Loosen screws securing bracket of pulley 4 and fit cord around this pulley. Remove paper wedge from between pulleys 5 and 6. Adjust bracket so that cord will move 1/8 inch when force of 1 1/4 to 2 ounces is applied vertically to cord at point midway between pulleys 4 and 5.

AE4533

Fig. F5 — Installation of pen drive cord in Model S recorder. All views of main pulley are from rear of instrument

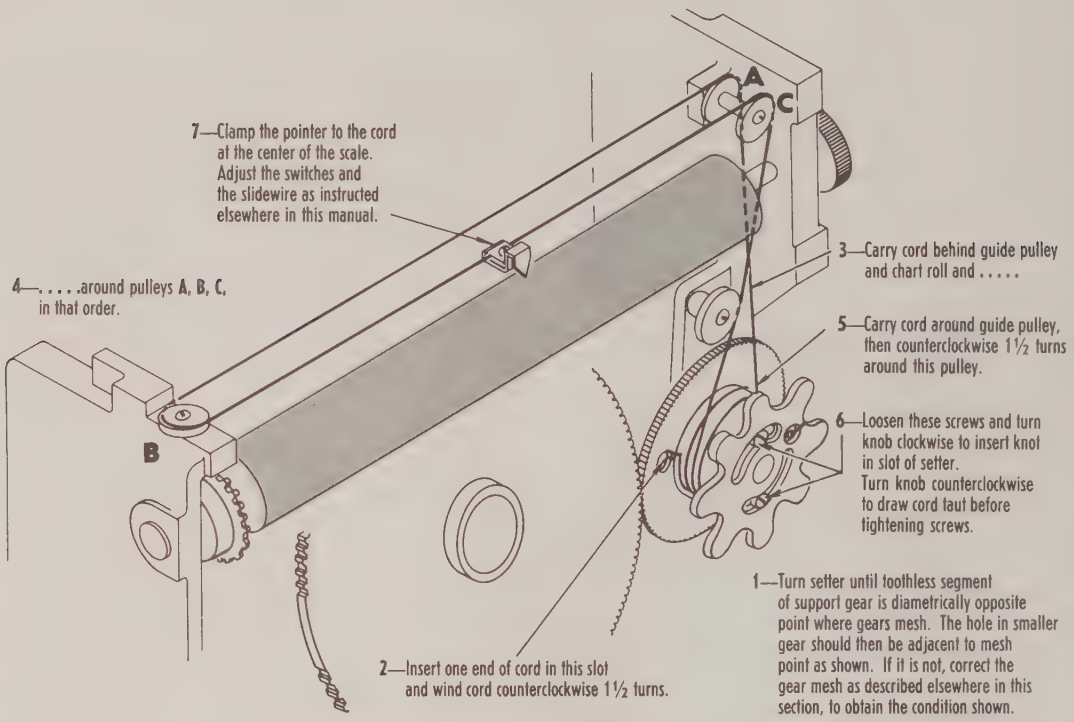

7—Clamp the pointer to the cord at the center of the scale. Adjust the switches and the slidewire as instructed elsewhere in this manual.
4—. . . . .around pulleys A, B, C, in that order.
3—Carry cord behind guide pulley and chart roll and . . . . .
5—Carry cord around guide pulley, then counterclockwise 1½ turns around this pulley.
6—Loosen these screws and turn knob clockwise to insert knot in slot of setter. Turn knob counterclockwise to draw cord taut before tightening screws.
1—Turn setter until toothless segment of support gear is diametrically opposite point where gears mesh. The hole in smaller gear should then be adjacent to mesh point as shown. If it is not, correct the gear mesh as described elsewhere in this section, to obtain the condition shown.
2—Insert one end of cord in this slot and wind cord counterclockwise 1½ turns.
A
B
C
E4535

Fig. F6 — Installation of set point setter drive cord in Model S recorder.

Model S Pen Drive Cord — Remove the chart and all pieces of the old cord. Then install the new cord according to the sequence of steps given in Fig. F5. Adjust the scale, pointer, and pen lineup and check for dead band as instructed in Section H.

Model S Set Point Setter Drive Cord — Remove the chart, chart platen, and all pieces of the old cord and install the new cord according to the sequence of steps given in Fig. F6. Then adjust the set point indicator position and the control settings as instructed in Section D.

SLIDEWIRE ASSEMBLY

Refer to Fig. F7 for identification of parts.

Caution: In removing or replacing any parts of the slidewire assembly, be careful not to damage the slidewire itself. In particular, do not allow the contacts to snap down on the slidewire since this may nick the wire and affect the instrument calibration.

Slidewire Contacts — To remove the contacts only, take out the two screws which hold the contacts and the small metal clamp plate to the end of the contact arm. When replacing the contacts or installing new ones, take care that each contact is centered over its corresponding slidewire.

When the slidewire contacts have been replaced, the contact setting should be checked as instructed in Section H.

Contact Arm — To remove the contact arm, loosen the socket-head capscrew and slide the arm from the end of the shaft. Take care not to bend the contact springs.

When reinstalling the contact arm, each contact must be centered over the corresponding slidewire. Also, the arm should not touch either the slidewire molding or the slidewire cover when this cover is replaced.

The contact arm is keyed to go on the shaft in the correct position. After replacing the arm, check the contact setting as instructed in Section H.

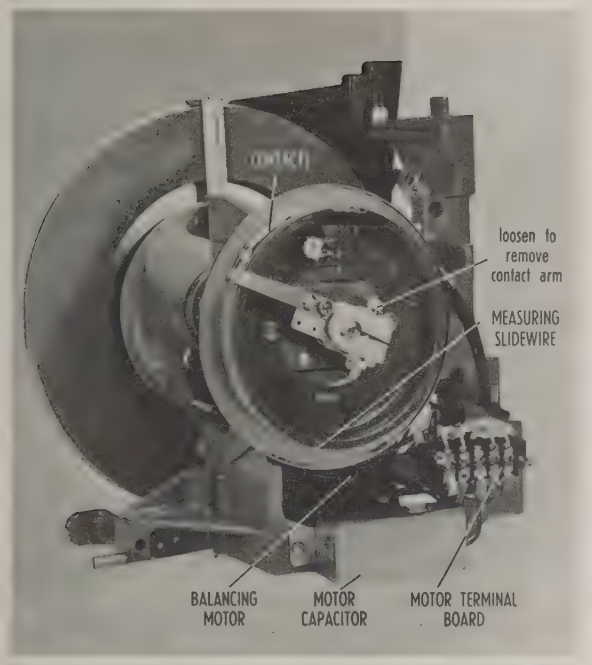
Slidewire — To free the slidewire, first remove the contact arm and then take out the two slidewire mounting screws. The complete slidewire molding, together with the rear slidewire shield, may now be removed.

When the slidewire is replaced, the contact setting should be checked and adjusted as instructed in Section H.

BALANCING MOTOR

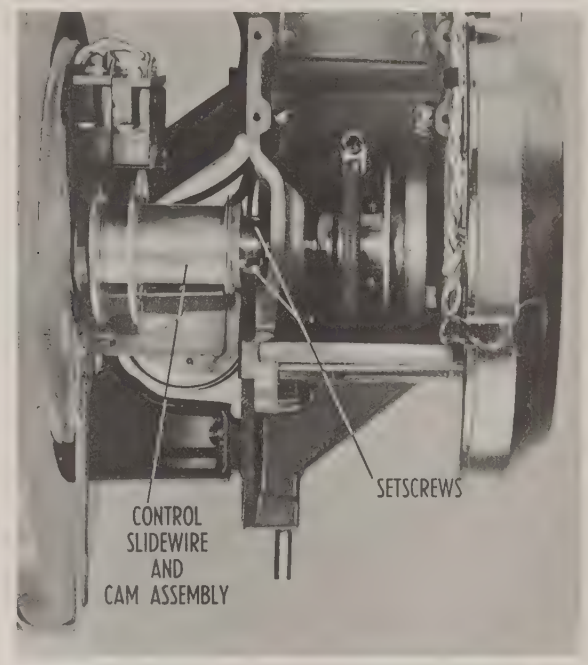
To remove the balancing motor, first disconnect the motor leads at the motor terminal board, Fig. J1. Then, using a 9/64" hex key, take out the three hex socket screws which hold the motor to the nutplate. Two of these screws are accessible from the bottom, the third from the top. Do not attempt to loosen or remove the motor mounting plate (also secured with hex socket screws) as this is a factory adjustment.

The balancing motor can now be withdrawn through the bottom of the casting. See Fig. F7.



E4536

Fig. F7 — Rear view of hinged casting.



E4529B

Fig. F8 — Top view of hinged casting.

When replacing the balancing motor or installing a new one, first orient the motor so that its nameplate faces the hinged side of the casting. Then replace the screws, adjusting the position of the motor and nutplate while tightening the screws, so as to obtain a good mesh, i.e., with minimum backlash, between the motor worm and the fiber worm gear on the slidewire shaft. See Section G for instructions on checking this mesh.

Finally, reconnect the motor leads to their appropriate terminals on the motor terminal board, Fig. J1.

CONTROL ASSEMBLY

Set Point Setter Assembly — Refer to Figs. F8, F9 and F10 for identification of parts. The initial procedure for the different models is as follows:

Model R Indicator—First pull off the pointer and remove the flexible leadwire clamp.

Model R Recorder—Remove the pen and swing the pen bracket down. Take off the chart platen, pointer arm, and flexible leadwire clamp.

Model S Recorder—Remove the chart platen and flexible leadwire clamp.

Now, upon removal of the retaining ring from the front of the slidewire shaft, the set point setter support gear, together with any switches and slidewire contacts, can be withdrawn from the shaft. *Depress the switch actuating levers when withdrawing this assembly, to clear the operating cams and prevent damage to switches. Care must also be exercised to prevent damage to the control slidewire.*

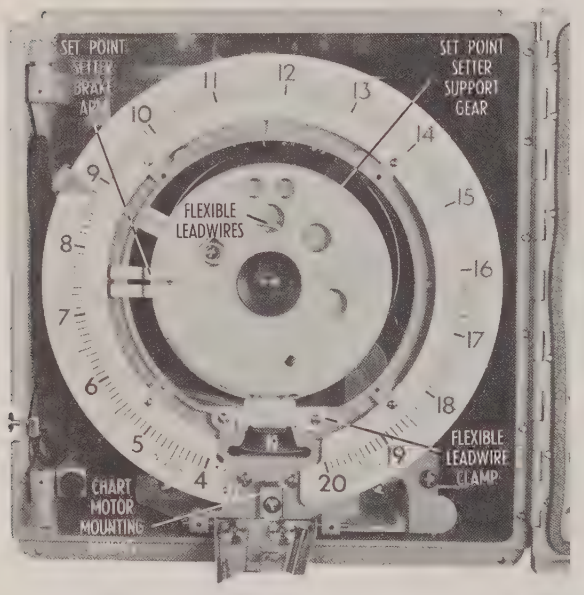
When replacing the set point setter on the Model S recorder, the support gear must be properly meshed with the smaller setter gear. The correct condition of mesh is illustrated in Fig. F6. Note that this condition can also be restored after the support gear is mounted, by removing the pivot screw from the center of the set point setter, remeshing the two gears, and then replacing the screw.

After the support gear is replaced, the flexible leadwires are to be wound clockwise from the hub out. With the set point setter turned to its counterclockwise (downscale) limit, the flexible leadwires must be wound snugly around the hub in a single layer, as shown in Figs. F9 and F10, before the leadwire clamp is mounted. Brake arm must engage pin as shown.

Upon replacement of the set point setter assembly, the settings of switches and/or slidewires should be checked and readjusted as directed in Section D.

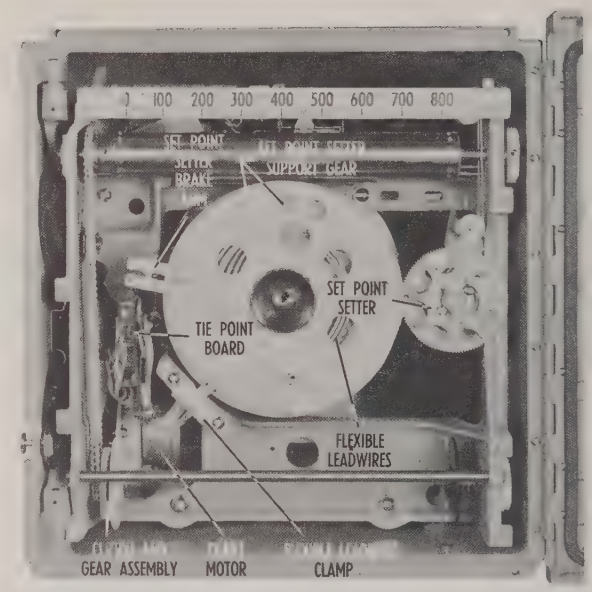
Control Slidewire and Cam Assembly — With the set point setter assembly removed as described above, the control slidewire and cam assembly can be removed as a unit by loosening the setscrews, Fig. F8, which hold the mounting sleeve to the slidewire shaft.

Upon replacement or installation of a control slidewire and cam assembly, mount the set point setter assembly before tightening the setscrews in the sleeve. Then with the support gear pulled forward against the retaining ring, adjust the sleeve to allow from .005″ to .01″ clearance between the sleeve and the support gear. Hold the sleeve in this position and tighten the setscrews onto the flats of the shaft. The clearance is to prevent binding of the assemblies during operation.



E4537

Fig. F9 — Model R instrument with chart platen removed.



E4538

Fig. F10 — Model S instrument with chart platen removed.

CHART MOTOR

Model R — With the instrument turned off, disconnect the chart motor leads at the motor terminal board. Remove the pen and swing the chart bracket down. Take out the two chart motor mounting screws, Fig. F9. This will allow the motor, together with its mounting bracket and drive disk to drop from the bottom of the chart casting.

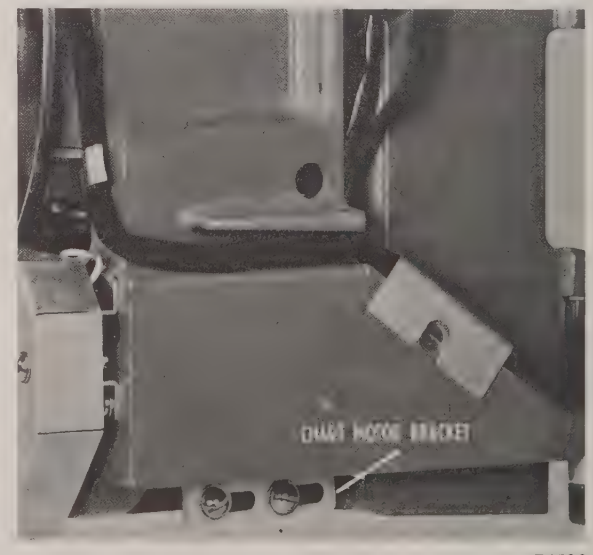
If a new chart motor is to be installed, loosen the setscrew and withdraw the drive disk from the shaft of the old motor. Remove the old motor from the mounting bracket and install the new one in its place. Mount the drive disk on the shaft of the new motor (spring washer *must* be placed between the bracket and drive disk).

Upon replacement of the chart drive motor in the instrument, the driving radius must be adjusted as specified in Section G, Model R Chart Drive.

Model S — With the instrument turned off, disconnect the chart motor leads at the motor terminal board. Remove the chart and chart platen. Then take out the screw from the center of the clutch and gear assembly, Fig. F10—this screw has a *left-hand* thread. Remove the clutch and gear assembly temporarily. Also remove the E washer from the left-hand end of the lower chart guide shaft and slide this shaft to the right until it is about half way out. These last two moves are simply to provide more space for the removal of the motor.

Remove the two screws, Fig. F11, which secure the motor mounting plate to the casting. Lift the motor, pinion and plate, as a unit, out through the opening left by the removal of the clutch and gear assembly and by the sliding of the chart guide shaft.

To replace the chart motor reverse the steps outlined above. Note that the motor pinion is to be mounted with its hub toward the end of the shaft. Before tightening the motor plate mounting screws, adjust the position of the plate to obtain a good mesh with the idler gear. Check backlash by observing shake in the idler gear; check for binding by rotating the motor pinion manually in a clockwise direction, as viewed from the end of the motor shaft.



E4539

Fig. F11 — Model S chart motor mounting screws are accessible from side of hinged casting.

PART II — SERVICING AND TROUBLESHOOTING . . . . .

Section G — MECHANICAL SERVICING

CONTACT FORCE ADJUSTMENTS

Instruments may come equipped with measuring and control slidewire contacts that are either cylindrical (●CONTACT) or half round (‿CONTACT) in shape. The type furnished can easily be determined through observation (see sketches above).

If the contacts are cylindrical, contact force is 35 to 45 grams; if half round, contact force is 2-3 oz. (56-84 grams).

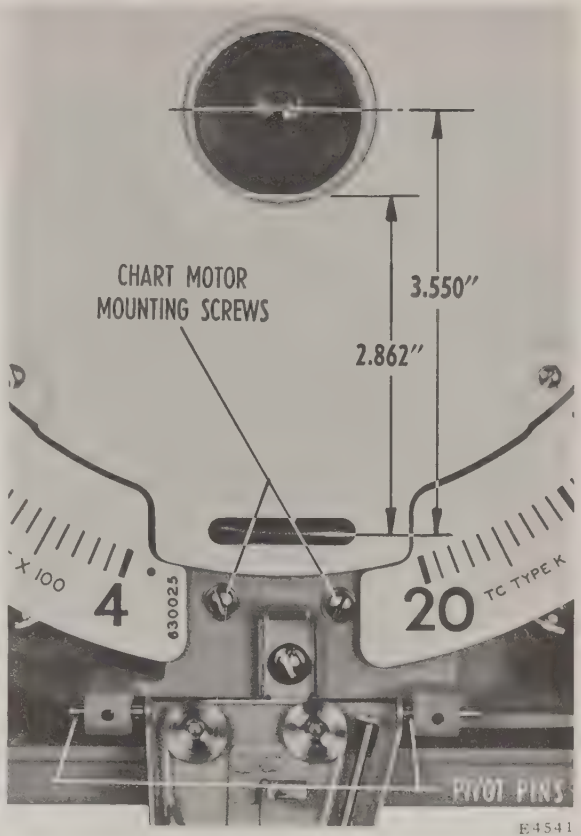
Both types are adjusted in the same manner. Make sure that readjustment, when required, is for the proper force. If the contact force is too low, unreliable electrical connection may result. Excessive force will cause rapid wearing of the contacts.

Caution: In making the following checks and adjustments, take care never to allow contacts to snap down on slidewires since this may cause nicking of the slidewires and affect calibration.

Measuring Slidewire——When the contacts are disturbed or new ones installed, the contact force should be measured and adjusted if necessary. Use a gram gage* (or equivalent) to make the measurement. With the instrument turned off, apply the gage so that it effects a straight pull perpendicular to the contact spring, as shown in Fig. G1. If the force required to just lift the contact off the slidewire is not within the limits stated above for the type of contact used, the force should be adjusted. Excessive contact force can be relieved by bending the contact outward without removing it from the instrument. To increase the force, the contact must be removed, bent, and reinstalled. After the contacts are reinstalled, the instrument calibration should be checked as instructed in Section H.

E4540

Fig. G1 — Slidewire contact force measurement.



E4541

Fig. G2 — Model R chart drive radius.

Control Slidewire——First, turn off all power to the instrument. Then turn the set point setter to make the control contact accessible. Rotate the slidewire shaft (by turning the hub of the measuring slidewire contact arm) until the contact rests on the wrapped portion of the control slidewire mandrel—not on the molding. Apply a straight radial pull to the contact leaf, adjacent to the contact itself. If the force needed to just lift the contact from the slidewire is not within the limits stated above for the type of contact used, readjustment is necessary. Excessive contact force can be relieved by bending the contact away from the slidewire. To increase the force, the contact must be removed, bent, and replaced.

MODEL R CHART DRIVE

The speed of the Model R chart is proportional to the drive radius (i.e., the distance from the chart center to the knurled edge of the drive disk). When the chart motor is replaced, or its position disturbed, it will be necessary to adjust the drive radius for correct chart speed.

The correct drive radius is given in Fig. G2. If desired, the measurement can be from the bottom of the chart hub as shown. Note that the right side of the drive disk should be inclined downward at an angle of 1.5 degrees below the horizontal. That is, at the right side of the slot in the chart platen, the disk should be approximately 0.010" lower than the center value given in Fig. G2; at the left side of the slot, the disk should

*Gage shown is 50-0-50, available from J.H. McCullough & Son, Industrial Division, 1248 N. Broad St., Phila., Pa. 19121 (Cat. #62-6387).

be 0.010″ higher than the center value. When the correct disk position is obtained, tighten the motor mounting screws to secure the adjustment.

It should be noted that error in chart speed will be in proportion to error in the drive radius setting. An error of .010″ in the radius setting produces an accumulated timing error of about four minutes in a 24-hour period. If the radius is too small, the chart runs fast, and conversely.

After the drive radius is adjusted, check the actual chart rotation for a three- or four-hour period. If a new motor has been installed, allow it to run for about twenty minutes before starting to check, to take up any backlash. Do not swing out the pen bracket during the check, since the chart stops when the bracket is out. If the accumulated error exceeds requirements, make a *very small* correcting adjustment to the drive radius and repeat the check.

MODEL R PEN BRACKET

To check the adjustment of the Model R pen bracket, turn the instrument off and manually rotate the hub of the measuring slidewire contact arm to bring the pointer to its downscale limit. Pull out the pen bracket knob and turn the chart so that the penpoint is on one of the radial time lines when the knob is re-engaged. Now, with the pen bracket closed, manually rotate the contact arm to bring the pointer to its high-end limit. The pen line thus drawn should coincide with the time line throughout its length. If it does not, loosen the setscrews which secure the pivot pins, Fig. G2, adjust the position of the pen bracket as required, and repeat the check.

CLUTCH ADJUSTMENTS

The instrument employs several clutches, as shown in Fig. G3. Each clutch consists of a spring washer arranged to be compressed by an adjustment nut. The clutches will not require adjustment unless they are disturbed. When necessary, the factory settings can be restored as instructed below.

Worm Gear Clutch — This clutch serves as a shock absorber when the mechanical balancing system is driven to either low or high end mechanical stop positions.

The clutch should not be set so tight that the fiber gear is locked to the shaft. The proper setting, as made by the factory, is for a torque between 5 and 7 inch pounds (in.-lb) for a 1-second response time instrument, or for an instrument with 5-second response time and equipped with balancing motor off-scale limit or desensitizing feature (option 026 or 027) and solid-state amplifier 444508 or 444509. For other 5-second response time instruments and all 2-second instruments, the torque setting should be between 10 and 12 inch pounds.

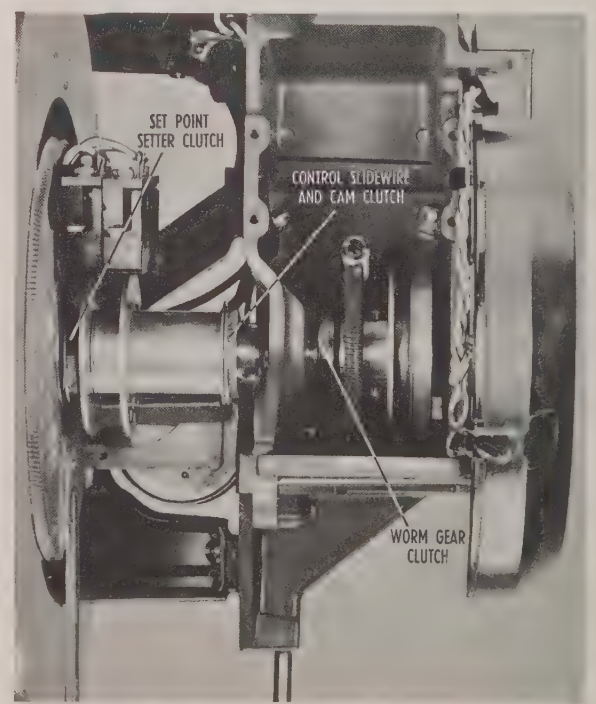
The torque measurement is made at the slidewire contact arm with the mechanism against a mechanical stop. Using a spring balance, attach it to the contact arm at a right angle to the direction of pull. Hold the worm gear securely in position and pull in a direction away from the mechanical stop. The distance from the center of the slidewire shaft to the contact point of the spring balance, multiplied by the spring balance reading, should equal the required torque.

Set Point Setter Clutch — This clutch is identified in Fig. G3. When it is properly adjusted, an applied torque of 5-7½ in.-lb is required to turn the set point setter support gear. The method of measuring the torque differs for Model R and Model S instruments.

Model R — Turn the set point indicator, Fig. D2, to the center scale (vertical) position. Then use a spring scale to apply a straight horizontal pull at the end of this arm (i.e., 5″ radius). The pull required to move the set point indicator should be from 1 to 1½ lb. If it is not, adjust the nut to obtain the correct condition.

Model S — Turn the set point setter to bring the indicator onscale. Then use a spring scale to apply a tangential pull to one of the finger notches of the setter as shown in Fig. G4. The pull required to move the indicator should be from 3 to 4 lb. If it is not, adjust the nut to obtain the correct condition.

Control Slidewire and Cam Clutch — This clutch is identified in Fig. G3. To adjust the clutch, first tighten the nut with moderate force, i.e., until the spring washer is completely flattened. Then back off the nut one flat from tight.



E4542

Fig. G3 — Speedomax H clutches.

MOTORS

Chart Motor — This synchronous motor cannot be repaired. If the motor fails to operate for any reason, it must be replaced with a new motor of the same voltage, frequency, and speed. Refer to Section F.

Balancing Motor — The two-phase balancing motor is equipped with end-sealed type ball bearings properly packed with grease before leaving the factory. They should, therefore, require no attention for at least a year and possibly two years. It is recommended that no lubricant be added to the bearings and that the bearings be replaced with new ones when they become objectionably noisy.

To replace the bearings, first remove the motor from the instrument as instructed in Section F. Then loosen the hex nut to remove the worm from the end of the motor shaft. Remove the two (diagonally opposite) through bolts which hold the motor end covers in place and tap the shaft end cover to loosen it. Remove this cover, noting the arrangement of any spacers, washers, etc., on the motor shaft. Lift the rotor from the motor frame, noting the arrangement of any spacers, washers, etc., on this end of the motor shaft.

Use a bearing puller to remove the old bearings from the rotor shaft. Press the new bearings (Leeds & Northrup Part No. 008052, packed with grease) on the shaft, taking care to apply pressure to the *inner ball race* only. The bearings must be pressed tightly against the shoulders on the shaft.

There is a slotted screw plug in one end cover of the motor for adjusting end shake. Before reassembling the motor, back this adjusting screw out (counterclockwise) approximately ¼ turn. A large locking nut around the adjusting screw must be loosened to permit the adjusting screw to be turned.

After the adjusting screw is backed out, replace the spacers, washers, etc., on the shaft in the original sequence and reassemble the motor. Then turn the end shake adjusting screw in until end shake of the rotor is just eliminated. *Do not turn this screw in beyond this point.* It is suggested that the adjusting screw be turned 1/16″ (on the periphery of the screw) at a time for each check for end shake. After end shake is just eliminated, back out the adjusting screw 1/16″ (on the periphery of the screw) and lock it in this position with the locking nut. If the above procedure is done correctly the motor shaft should turn freely.

Replace the worm on the motor shaft and tighten in place with the hex nut. Then replace the motor as instructed in Section F, taking care to maintain proper mesh between gears as outlined below.

BALANCING MOTOR GEAR MESH

The balancing motor worm must mesh with the worm gear without binding and with minimum backlash. To check this condition first check that the worm is centered on the teeth of the worm gear. Then use a screwdriver to turn the worm. This worm should rotate freely for all positions of the measuring slidewire shaft.

E4543

Fig. G4 — Measurement of set point setter clutch torque on Model S recorder.

To check backlash in the gear mesh, feel the lost motion in the measuring slidewire contact arm. For any position of the arm, the lost motion should not exceed .020″ as measured at the measuring slidewire contact. This is approximately equivalent to 2 or 3 of the fine wire turns on the measuring slidewire.

If the motor worm is not centered on the worm gear as outlined above, adjust the motor as described in Section F, Balancing Motor. If necessary, the worm gear can be moved slightly by loosening the setscrews in the worm gear clutch assembly, sliding the assembly the required amount, and then tightening the setscrews.

MODEL S PEN FORCE ADJUSTMENT

The penpoint of the Model S recorder should bear against the chart with a force between 10 and 15 grams. If the force is less than 10 grams, the pen will probably skip; if it is more than 15 grams, the pen will probably pick up paper fibers and become clogged or even tear the chart. To correct for the former condition, bend the pen bias spring, Fig. B7, towards the top of the recorder; to correct for the latter condition, bend the pen bias spring towards the bottom of the recorder. A lighter force is preferable for highly active recording, a heavier force for large-excursion, high-speed type recording. See also Section E, Recorder Inks.

PART II — SERVICING AND TROUBLESHOOTING . . . . .

Section H — CALIBRATION

This section outlines proper procedures for checking calibration accuracy of the Speedomax instrument. Such an accuracy check will be required when measuring circuit components are disturbed — e.g., after removal and replacement of the measuring slidewire, installation of new slidewire contacts, etc. The user may also wish to check the calibration periodically.

PRELIMINARY

Before proceeding with the calibration check itself, check the regulated power supply as instructed in Section L. In addition, perform the following checks and adjustments regardless of the kind of measuring circuit used in the instrument. Make sure that the instrument has warmed up for at least 30 minutes.

On instruments with low millivolt spans (2 mV or less), avoid the unnecessary use of terminal lugs or clips on any connecting leadwires. On thermocouple instruments it is advisable to wrap the incoming wires directly around the screw terminals and tighten securely.

Note that in the Speedomax instrument, the length and resistance of the measuring slidewire is actually two percent greater than required for the calibrated scale span. This allows for overtravel at both the low end and high end of the scale. The reason for overtravel is that it permits checking of instrument calibration at the extreme ends of the scale span. If no overtravel were provided, it would be hard to tell whether the instrument was balanced at the scale end or whether it had simply stalled against the mechanical stop without achieving balance.

SCALE, POINTER, AND PEN LINEUP

The instrument should be turned off during the following checks.

Model R Indicator or Recorder — Turn the hub of the slidewire contact arm to bring the pointer downscale until the low-end stop is reached. Under this condition, the pointer should be at the low-limit mark (dot) below the calibrated part of the scale. If it is not, disengage the pointer from the slidewire shaft and slightly loosen the three screws in the pointer retaining plate, just enough that the pointer is held in place by the pressure of the retaining plate and yet can be rotated by moderate force. Then re-engage the pointer on the shaft. With the contact arm held firmly against the low-end stop, rotate the pointer until the condition specified above is met. Pull out the pointer again and tighten the screws in the retaining plate. Then check the pointer setting once more. This completes the lineup for the model R indicator. For the Model R recorder, continue as instructed below.

Model R Recorder Only — With the slidewire arm turned to the low-end stop as instructed above, the recorder penpoint should be on the first line of the chart. If it is not, swing out the pen bracket and loosen the pen carriage screws just enough to allow the carriage to be pushed along the cord without moving of its own weight. Close the pen bracket and slide the pen carriage along the cord until the condition specified above is met. Swing out the pen bracket again and tighten the pen carriage screws. Then check the pen setting once more. This completes the lineup for the Model R recorder.

Model S Recorder — Turn the hub of the slidewire contact arm to bring the pen downscale until the low-end stop is reached. Under this condition, the penpoint should be on the first line of the chart. If it is not, loosen the screw which holds the pen carriage to the drive cord and slide the carriage along the cord.

With the slidewire contact arm still held against the low-end stop, the pen carriage pointer should be at the low limit (dot) below the calibrated part of the scale. If it is not, loosen the screws at the ends of the scale and shift the scale to obtain the specified condition. Then tighten the screws to hold the scale in place.

INSTRUMENT DEAD BAND

If the various components, both electrical and mechanical, have been properly adjusted, the dead band should be negligible, i.e., 0.15% or less of full scale on most instruments. It is advisable, however, to make a direct check of instrument dead band before proceeding with calibration since excessive dead band may appear as a calibration error.

Dead band can be defined functionally as the difference between the final scale readings for upscale and downscale approach to balance, respectively, the measured quantity being the same in each case. Thus dead band is measured by displacing the scale reading, first in one direction and then in the other, and measuring or observing the difference between the two balance points.

Two methods are suggested. One requires the use of a precision reference potentiometer such as a Leeds & Northrup Type K Potentiometer, or equivalent (see Table H1); the other is a field check which simply makes use of manual displacement of the balancing motor worm.

On instruments with a 5-second step response, one revolution of the worm on the balancing motor shaft is equivalent to about 1% change in instrument reading; for a 1-second step response, 1/6 revolution is about a 1% change. A screwdriver slot is provided in the motor worm to permit manual rotation.

Where a precision potentiometer is available, the Potentiometer Method is to be preferred because it is the more accurate of the two methods.

Potentiometer Method — Proceed as follows:

(1) Disconnect the usual input from the terminal board. Then connect the leads from the reference potentiometer to these same terminals, observing polarity.Δ

(2) Standardize the current of the reference potentiometer.

(3) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil.

Δ If the instrument is equipped for TC or Rayotube range card input failsafe, or emf battery failsafe -- see Section L - remove the jumper (TC/Rayotube) or battery (emf).

(4) Set the gain adjustment of the instrument to provide minimum dead band as instructed in Section B, Adjust Amplifier Gain.

(5) Set the reference potentiometer to a value near midscale so that both pointer and pen are directly on a line of the chart paper.

(6) Change the setting of the reference potentiometer until the instrument indication is greater than the original value by an amount equal to approximately twice the accuracy rating. Slowly reset the reference potentiometer to the original value. Observe the instrument reading.

(7) Change the setting of the reference potentiometer until the instrument indication is less than the original value by an amount equal to approximately twice the accuracy rating. Slowly reset the reference potentiometer to the original value. Observe the instrument reading.

(8) Take the difference between the readings obtained in steps 6 and 7. This is the dead band and it should not exceed 0.15% of the scale span.

(9) Repeat the above procedure near the low and high ends of the scale.†

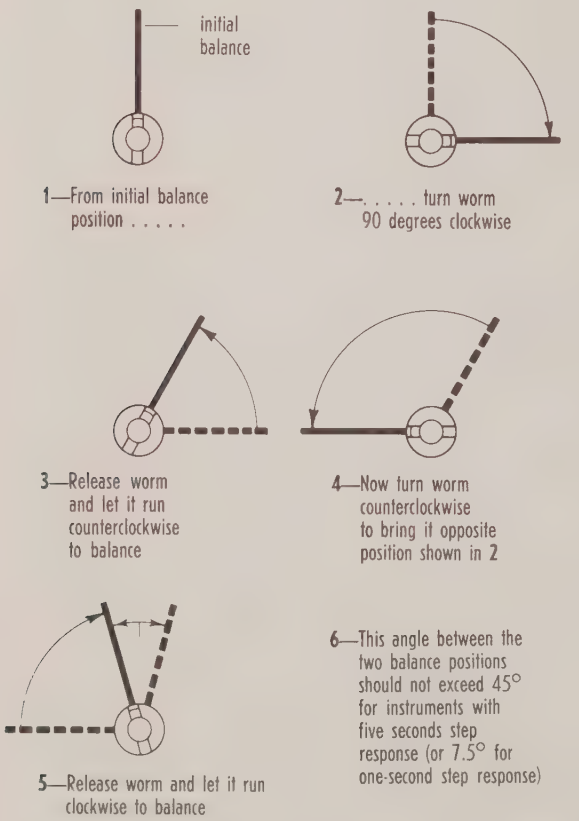

initial balance
1—From initial balance position . . . . .
2—. . . . . turn worm 90 degrees clockwise
3—Release worm and let it run counterclockwise to balance
4—Now turn worm counterclockwise to bring it opposite position shown in 2
5—Release worm and let it run clockwise to balance
6—This angle between the two balance positions should not exceed 45° for instruments with five seconds step response (or 7.5° for one-second step response)
E4545

Fig. H1 — Method of checking dead band by observing balancing action at balancing motor worm.

Motor Worm Displacement Method —

Caution: The dead band check given here is not valid if there is excessive backlash in the mesh of motor worm and worm gear. Check this mesh as instructed in Section G, Balancing Motor Gear Mesh.

With the instrument turned on, apply a fixed input to its measuring terminals to bring the reading on scale. Then check the dead band as instructed in Fig. H1. The dead band, measured in this manner, should be 45 degrees (approximately 0.15% of full scale) or less for any 5-second balance instrument whose millivolt scale span is 2 mV or greater. For spans below 2 mV with 5 seconds balancing, the permissible dead band will be proportionately greater than 45 degrees.

A dead band in excess of the 45 degrees (approximately 0.15% of full scale), as measured above, can usually be corrected by replacing badly worn measuring slidewire contacts, by increasing the amplifier gain or by adjusting any binding in the mechanical components of the balancing or indicating systems. Check and adjust or replace these items as indicated in Sections F, G, J, and K.

The millivolt scale span of a potentiometer instrument can be determined from the data on the instrument nameplate. In the case of bridge instruments, calculate the resistance span from the nameplate data, and use the equivalent millivolt span — approximately equal to three times the resistance span in ohms — for determining the permissible dead band.

ZERO-OFFSET ADJUSTMENT

On low millivolt spans—usually 5 mV or less—offset voltages generated in the amplifier or injected into the amplifier via external recorder circuitry, may show up as errors in the actual measurement. A zero-offset adjustment, Fig. B11, is provided to reduce these offset voltages to virtually zero. Above 5 mV offset voltages can generally be ignored because of the small percentage error they represent with respect to the entire span. This offset adjustment has been set at the factory but should be checked and adjusted if necessary just prior to instrument calibration. The amplifier and power supply should be warmed up and the amplifier gain set at optimum.

To check and adjust for zero offset: Momentarily turn off power to the instrument and remove the amplifier cover. Short out the power supply output terminals—pins 1 (+) and 3 (−) on the power supply side of the plug-in connector (not on the amplifier side). See Fig. L8. If a mercury cell is used instead of a regulated power supply, remove the mercury cell from the holder and short across the holder contacts (from + to −).

Caution: Be careful not to short the mercury cell as to do so may cause it to explode.

Also, short out the recorder input terminals. Then turn the power back on, allowing for a continuous warmup time of 5 minutes. Be careful not to touch components or wiring on either card.

† Replace jumper/battery.

With the measuring pointer at some location between scale limits, note whether the pointer creeps or drifts in either direction. If creeping is detected, adjust the zero-offset control, Fig. B11, until the pointer stops driving, but not against an upscale or downscale limit position. That is, the pointer should come to rest at some position between scale limits and draw a straight line without drifting. When this operation has been satisfactorily completed, turn off power to the instrument. Remove the jumpers (and replace the mercury cell where applicable), and replace the amplifier cover. Turn the power back on and proceed to calibrate the instrument as instructed below.

CALIBRATION PROCEDURE

Table H1 lists Leeds & Northrup potentiometers suitable for calibration purposes. The smaller the limit of error listed the better the accuracy of measurement. Wherever possible, therefore, the calibration of the Speedomax instrument should be checked with a potentiometer whose accuracy and resolution are several times better than the instrument being checked since the validity of the check depends upon how accurate the reference value is known. Such reference potentiometers include the Cat. 8686 and 8687, 8690 and 8691, and any in the Cat. 7550 Series listed.

However, in many cases a reference potentiometer of less accurate means is adequate and the expense of a more precise unit not warranted. Instruments that fall within this category are those in the Cat. 8692 through 8696 Series listed. In this type of potentiometer the accuracy of measurement can be improved if the potentiometer is first checked against one of the standard types (7554, 7555, 8690, etc.) and a calibration curve developed. In this way, the error or deviation can be taken into consideration and the Speedomax instrument checked with a higher degree of accuracy than would be possible without the aid of the calibration curve.

It should be noted that in the Cat. 8692-8696 Series potentiometers listed, the limit of error, stated in terms of percent of span, applies only when the span of the instrument being checked is the same as that of the checking potentiometer. If the span of the instrument being checked is smaller than that of the checking potentiometer, the limit of error increases. For example, if the range of the checking potentiometer is 0 to 2000° F, or a span of 2000° F, 0.3% of 2000° F equals 6 degrees. Thus, the error is ±6° F, applicable at any point on the scale. When applied to a recorder range of, say, 0 to 200° F, the error amounts to 3% at the 200° F point and to 6% at the 100° F point.

From this it can be seen that wherever feasible, the span of the checking potentiometer and that of the instrument being checked should be the same or nearly so. The above does not apply to reference potentiometers where the limit of error is stated in percent of reading. In this case the error as a percent of reading applies, as indicated.

In general, a thermocouple potentiometer is used for making thermocouple measurements only, and then only for the type of thermocouple for which it is calibrated. An emf potentiometer, on the other hand, is suitable for making both emf and thermocouple measurements. Some potentiometers are equipped with more than one range, depending upon user convenience and/or accuracy requirements. The procedures outlined below cover the use of both emf and thermocouple types.

Where the calibration is not within the required accuracy, the troubleshooting instructions given in Sections J and K will help to locate the fault. Calibration errors may be due to such causes as faulty regulated power supply, nonlinearity of the slidewire, etc.

Slidewire Adjustment — It is suggested that, when feasible, the calibration be checked at more than one point — preferably at the center and at each end of the scale. If the calibration is outside the stated accuracy at any point on the scale, it can often be corrected by adjusting the balance position of the measuring slidewire. To adjust the balance point, remove the slidewire cover; then loosen the two screws securing the slidewire molding in position and rotate the molding the required amount. Then retighten the screws and replace the slidewire cover. Recheck the accuracy at several scale points to be certain that all points are within stated accuracy.

EMF POTENTIOMETER CIRCUIT

If the potentiometer measuring circuit used is for millivolt measurements and no automatic reference junction compensation is employed, calibration is checked by direct comparison with an applied emf obtained from a reference emf potentiometer of a type listed in Table H1.

Proceed as follows:

(1) Disconnect the usual input leads. Use copper wire to connect the emf terminals of the reference potentiometer to the Speedomax input terminals. Polarities should correspond.Δ

(2) Standardize the current of the reference potentiometer.

(3) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil. This is also necessary to prevent high input impedance of electronic null detectors from interfering with the measurement by decreasing sensitivity.

(4) Set the reference potentiometer to the emf value at which it is desired to check the calibration of the Speedomax instrument. The scale reading should correspond to the reference potentiometer setting within the combined accuracy of both instruments.††

THERMOCOUPLE POTENTIOMETER CIRCUIT

Many L&N temperature measuring devices furnished after January, 1973 are calibrated based upon the International Practical Temperature Scale of 1968

Δ If the instrument has battery failsafe — See Section L — remove the battery.

†† Replace the emf failsafe battery.

TABLE H1 — LEEDS & NORTHRUP REFERENCE POTENTIOMETERS

CAT. NO.	DESCRIPTION	RANGES	LIMITS OF ERROR**	MEASUREMENT
7554 7554-1 ▼	Type K-4, guarded	3	±(0.005% of reading + 20 μv)	EMF
7555 7555-1 ▼	Type K-5, guarded	3	±(0.003% of reading + 3 μv)	EMF
7556 7556-1 ▼	Six-dial, guarded	3	±(0.0005% of reading + 1 μv)	EMF
7564 7564-1 ▼	Differential Type	6	50-150 ppm, depending upon range	EMF
8686	Portable, millivolt with or without reference junction compensation	1	±(0.03% of reading + 3 (6*) μv)	EMF/TC
8687	Portable, volt	2	±(0.03% of reading + 30 μv)	EMF
8690	Portable, millivolt with or without reference junction compensation	1	±(0.05% of reading + 15 (30*) μv)	EMF/TC
8691	Portable, millivolt	2	±(0.05% of reading + 150 μv)	EMF
8692	Portable, temp.	1	±0.2% of span	TC
8693	Portable, temp.	2	±0.2% of span	TC
8694	Portable, temp.	1	±0.3% of span	TC
8695	Portable, temp.	2	±0.3% of span	TC
8696	Portable, millivolt with or without reference junction compensation	2	±(0.3% of span + 45* μv)	EMF/TC

▼ Designed for rack mounting.

** Figures listed are for highest range where applicable. Limit of error diminishes on lower ranges.

* With reference junction compensation.

(IPTS-68). The scales and range cards of such instruments are identified with the thermocouple letter designation and calibration year; for example J68. The temperature/emf relationship for these instruments is listed in L&N booklet 177610.

Instruments without the "68" designation are calibrated based on IPTS-48 for which the temperature/emf relationship is listed in L&N booklet 077989.

The procedure for checking calibration of a thermocouple potentiometer measuring circuit is similar to that for an emf potentiometer measuring circuit in that a potentiometer (see Table H1) is used as the reference emf source. It differs, however, in that when checking with an emf potentiometer, thermal emf's generated at junctions of copper wires and thermocouple extension wires must be taken into account. Any of the following methods may be used in making the check, depending upon equipment available.

Ice Bath Method — In this method, the reference emf potentiometer is connected to the Speedomax instrument in the manner shown in Fig. H2. The junctions formed at the connections of copper and extension wires are held at 32° F (0° C). In effect, this circuit constitutes a thermocouple with its measuring junction at 32° F, in series with the emf of the reference potentiometer. Such a thermocouple has zero output when referred to an emf vs. temperature conversion table whose reference temperature is 32° F. Thus the effective temperature input applied to the thermocouple measuring circuit is equal to the temperature equivalent of the reference potentiometer setting as obtained from the same conversion tables.

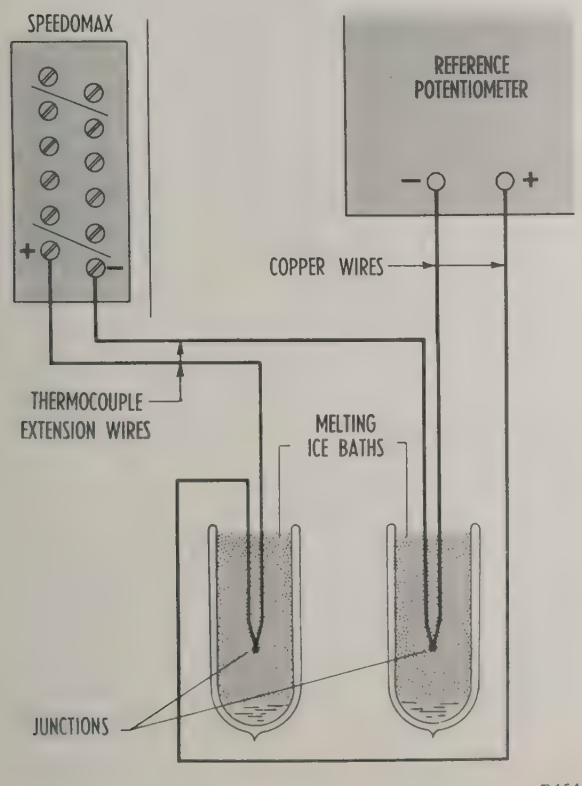


Fig. H2 — Connections for calibrating thermocouple potentiometer by ice bath method.

Proceed as follows:

(1) Disconnect the measuring thermocouple leads from the terminal board. Using extension wire corresponding to the type of thermocouple in use, connect these wires to the Speedomax input terminals. Polarities should correspond. Δ

(2) Use well-compacted melting crushed-ice baths (ice made from distilled water) for maintaining the temperature of the copper-to-extension wire junctions. It is also permissible to use a single ice bath, provided the junctions are electrically insulated with a coating of paraffin.

(3) Immerse the junctions at least four inches in the ice baths and allow time for them to reach ice bath temperature.

(4) Standardize the current of the reference potentiometer.

(5) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil. This is also necessary to prevent high input impedance of electronic null detectors from interfering with the measurement by decreasing sensitivity.

(6) Set the reference potentiometer to the emf equivalent of the temperature at which it is desired to check the calibration. Use the emf vs. temperature conversion table for the type of thermocouple normally employed for measurement — reference temperature of the tables must be 32° F (0° C). The scale reading should correspond to the reference potentiometer setting within the combined accuracy of both instruments.‡

Field Methods — Under field conditions two variations in checking calibration are possible, depending upon the type of potentiometer available. For example, if the potentiometer has a temperature range, it can be used to check instruments having automatic reference junction compensation and temperature ranges within the potentiometer's range. The only requirements are that the range for which the potentiometer is calibrated, i.e., iron-Constantan, Chromel-Alumel, etc., the type of thermocouple, and the extension wires, must all agree. If the potentiometer has a millivolt range, it can be used to check instruments having automatic reference junction compensation and temperature ranges within the equivalent millivolt range of the potentiometer, when used with the proper conversion tables.

Potentiometer with Temperature Range — Proceed as follows:

(1) Disconnect the measuring thermocouple leads from the terminal board. Using extension wire corresponding to the type of thermocouple in use, connect the terminals of the reference potentiometer to the Speedomax input terminals. Polarities should correspond. Δ

Δ If the instrument has input failsafe — see Section L — remove emf input failsafe jumper on the range card.

‡ Replace the range card failsafe jumper.

(2) Standardize the current of the reference potentiometer.

(3) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil. This is also necessary to prevent high input impedance of electronic null detectors from interfering with the measurement by decreasing sensitivity.

(4) Set the reference potentiometer to the temperature value at which it is desired to check the calibration. The scale reading should correspond to the reference potentiometer setting within the combined accuracy of both instruments.‡

Potentiometer with Millivolt Range — As indicated by Fig. H3, the reference potentiometer is connected to terminals at the input terminal board. In effect, this circuit constitutes a thermocouple with its measuring junction in series with the emf of the reference potentiometer. The emf equivalent of this thermocouple must be taken into account when setting the reference potentiometer to correspond to a given temperature check point.

Proceed as follows:

(1) Disconnect the measuring thermocouple leads from the terminal board. Using copper wire, connect the emf terminals of the reference potentiometer to the Speedomax input terminals. Polarities should correspond.Δ

(2) Using a calibrated mercury thermometer with a range covering the ambient temperature and an accuracy better than that of the instrument being calibrated, measure the temperature at the terminal board where the copper wires from the reference potentiometer connect to the measuring circuit extension wires. See Fig. H3.

(3) Standardize the current of the reference potentiometer.

(4) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil. This is also necessary to prevent high input impedance of electronic null detectors from interfering with the measurement by decreasing sensitivity.

(5) Allow sufficient time for the temperature to stabilize by checking the thermometer reading periodically until successive readings indicate a stable temperature. Note this temperature reading.

(6) From the emf vs. temperature conversion tables for the type of thermocouples normally used in the measurement, determine the emf which corresponds to the stable reading of the mercury thermometer. From the same tables determine the emf equivalent of the temperature at which it is desired to check the thermocouple calibration. The algebraic difference between these two emf's is the required reference potentiometer setting.

(7) Set the reference potentiometer to the value determined in step 6. The scale reading should correspond to the reference potentiometer setting within the combined accuracy of both instruments.‡

BRIDGE INSTRUMENTS

A special checking resistor may be purchased from L&N to calibrate a bridge type instrument. This precision resistor permits a rapid calibration check at one point of the instrument scale. To make the check, disconnect the primary element at the terminal board and connect the checking resistor in its place. The instrument reading should correspond to that specified on the checking resistor within ±0.3% of scale span.

It is also possible to check the instrument calibration at one or more points with resistance standards or other high precision reference resistors. Temporarily disconnect the primary element at the terminal board and connect the reference resistance in its place. Use three leads just as in the original connections, being careful that the leads connecting to terminals A and B are of equal resistance.

If the instrument reads resistance directly, adjust the reference standard to the value at which the check is to be made. Otherwise, set the reference standard to the resistance equivalent of the desired check point (use the proper conversion tables for the primary element normally employed with the instrument). The instrument reading should be correct within ±0.3% of scale span.

E4547

Fig. H3 — Use of thermometer in field calibration of thermocouple potentiometer instrument. Leadwires from reference potentiometer connect to (+) and (−) terminals.

Δ If the instrument has input failsafe — see Section L — remove emf input failsafe jumper on the range card.

‡ Replace the range card failsafe jumper.

PART II — SERVICING AND TROUBLESHOOTING . . . . .

Section J — LOCATING TROUBLE

In some cases of faulty instrument operation, the source of trouble will be immediately apparent. In others, this will not be the case since a given symptom may often be due to any one of several causes. In locating and eliminating such faults, two methods are recommended:

(1) When trouble arises, a number of simple preliminary checks, listed later in this section, should be made before proceeding with more elaborate tests. These simple checks, which can be performed without disturbing any components of the system, are designed to detect or correct those troubles most likely to occur.

(2) If the trouble is not located or remedied by the simple preliminary checks, a series of tests, also described later in this section, can be used to isolate the fault to one of the major sections of the system. When this is done, the faulty section can then be checked systematically to locate the particular component causing trouble.

INTERFERENCE

A special class of instrument troubles may arise from the introduction of spurious electrical signals (interference) into the amplifier. Such signals, commonly referred to as noise, pick up, and hash, are ordinarily due to special characteristics of the installation, rather than to faults in the instrument itself. Since interference signals may enter the circuits in various ways and may not be directly detectable with ordinary measuring equipment, the elimination of interference effects is often complicated. The discussion which follows is intended to present a practical approach to the recognition and correction of some common interference problems.

Interference Effects—From the point of view of instrument performance, interference signals fall into two groups: (1) signals which produce balancing motor torque and thus cause a shift in instrument calibration: (2) signals which do not produce motor torque but which appear as noise in the amplifier signal channel, overloading the amplifier and causing sluggish operation and excessive dead band. Both types of interference may exist simultaneously, resulting in a combination of these effects. In addition, if the interference source is variable or intermittent, the adverse effects will also be of an erratic nature.

Note: This discussion concerns only those interference effects arising from the conditions of the instrument installation—not those due to faulty components within the instrument itself. It should be noted, however, that the types of faulty performance described above may be caused by failure of transistors, filter capacitors, or other amplifier parts. Thus, if such symptoms are observed, the amplifier should be eliminated as a source of trouble before any further steps are taken. This is most conveniently done by replacing the amplifier with one known to be good and observing whether the interference effects are eliminated.

Causes—The usual causes of interference stem from: (1) direct current sources such as the use of dissimilar metals in connections to the primary element; (2) inductive or capacitive coupling of low frequency ac or dc switching circuits; (3) 50 or 60 Hz power line frequency sources and their harmonics, and (4) radio frequencies (rf).

Coupling to the instrument is effected in a number of ways. One is by conductance. This usually occurs in the case of an installation with a grounded primary element, e.g., a thermocouple, which is subject to picking up ground circulating currents. A second way is by magnetic coupling, commonly known as transformer action. If the measuring input circuit is in close proximity to a magnetic field produced by ac or intermittent dc, a portion of this field may be coupled to the input. A third way is by capacitive coupling. This occurs by virture of the fact that two wires in close proximity with each other or one wire with ground form in effect a capacitor. Currents traveling through one can, therefore, be coupled to the other—which may be one of the input leads. A fourth way is by rf radiation or simply strong radio wave propagation. Signals picked up in everyday radio reception is typical of this source, but at a considerably reduced potential.

Normal Mode—The type of interference coupling referred to above produces two modes of interference. One is normal mode, also called differential or series mode opposed mode or transverse. This type develops across the primary element leads and enters the instrument circuit in the same manner as the quantity being measured. It is seldom a serious problem because the input filter is designed to attenuate ac voltages developed across the input leads. Normal mode dc interference, which may be caused by thermal emf's, can usually be prevented by avoiding the use of dissimilar metals in the connections to the primary element.

Common Mode—The second mode of interference is common mode, also referred to as longitudinal or in-phase interference. It develops between the primary element circuit and ground, and can be either ac or dc or a combination of both. Ac common mode interference is the more troublesome, and is attributable to (1) primary element and instrument case at different ac ground potentials, or (2) primary element connected to ac voltage or current source.

Interference can also originate in the 120-V ac supply to the instrument. This condition is particularly likely when the power line is ungrounded or is at a different ground potential than the instrument case or primary element. Interference entering the system from the power supply is indistinguishable in its effects from that entering through the primary element circuit.

Eliminating Interference—If the instrument exihibits the faulty performance effects attributable to interference and the amplifier has been eliminated as a source of trouble, proceed as follows:

(1) Check to be sure all connections have been made in accordance with Section A. This includes input wiring

connections and the inclusion of an isolating transformer, if required, to ground the L2 side of the line supply.

The 4 μF input filter capacitor can also be disconnected for reduction of common-mode voltage, where applicable. Simply disconnect the white wire on this capacitor and tape the exposed lead. Further improvement can often be had by substituting a smaller capacitor for the 4 μF size. A value down to 0.05 μF may be found acceptable. Do not make this change for normal-mode interference.

(2) Check for a good single-point ground. Multiple grounds on the measuring circuit can be found by disconnecting the intended ground and rechecking for continunity to ground.

(3) Check the path of the input extension wires to be sure there is adequate separation from any motors, transformers, belt drives, ac and dc power lines, and ac or dc high-level signalling circuits.

PRELIMINARY CHECKS

Before proceeding with the more complicated isolation tests, follow the simple checking and replacement procedure given in Table J1. These steps will rapidly locate or remedy the great majority of instrument faults.

If a spare amplifier is not available, the existing one can be tested rather than replaced. Section K describes the testing procedure. In all cases, however, replacement is preferable since it is both faster and more reliable. And if more than one Speedomax instrument is available it is a simple matter to temporarily substitute the amplifier from the properly operating instrument for the one in the faulty instrument.

ISOLATION TESTS

If the trouble has not been located or corrected by simple preliminary checks, the tests given here will isolate it to one of the three major sections: (1) the measuring circuit, (2) the amplifier, or (3) the balancing motor circuit.

Balancing Motor Test—The balancing motor can be tested simply by disconnecting the control winding (yellow and green) leads and placing them in series with a resistor, across the line terminals of the motor terminal board as indicated in Fig. J1 (but first check that line voltage is present at the line terminals). The motor should run easily in one direction. Reversing the control winding leads should cause the motor to run in the opposite direction. Be sure that the resistor is always in the control winding circuit when making this test. The resistor should be such that the maximum voltage applied to the control winding (75-ohms ac impedance, 25-ohms dc resistance) is 25 volts or less.

Example:

A 300-ohm, 30-watt resistor.

A higher-value resistance, e.g, 1000-ohm, 10-watt, can also be used. Motor rotation in this case, however, will be somewhat slower than with the lower-value resistance.

If the motor runs as stated, the trouble is in the amplifier or the measuring circuit. If it does not, the 1.1 μF rectangular line winding capacitor (motor capacitor, Fig. F7), or the balancing motor is at fault. Disconnect the capacitor and test it as instructed in Section K, General Test Information, Capacitor Testing. Check the continuity of the motor windings. Resistance between windings and between each winding and motor housing should be infinite. Replace the defective component where necessary.

Amplifier Test—Although the following test involves both the amplifier and balancing motor, it is effectively a test of the amplifier only since the motor is assumed to have been checked as described above.

Proceed as follows:

Remove the amplifier cover and energize the instrument. Using a Simpson Model 260 volt-ohmmeter or equivalent, set it on the RX100 scale and apply the test

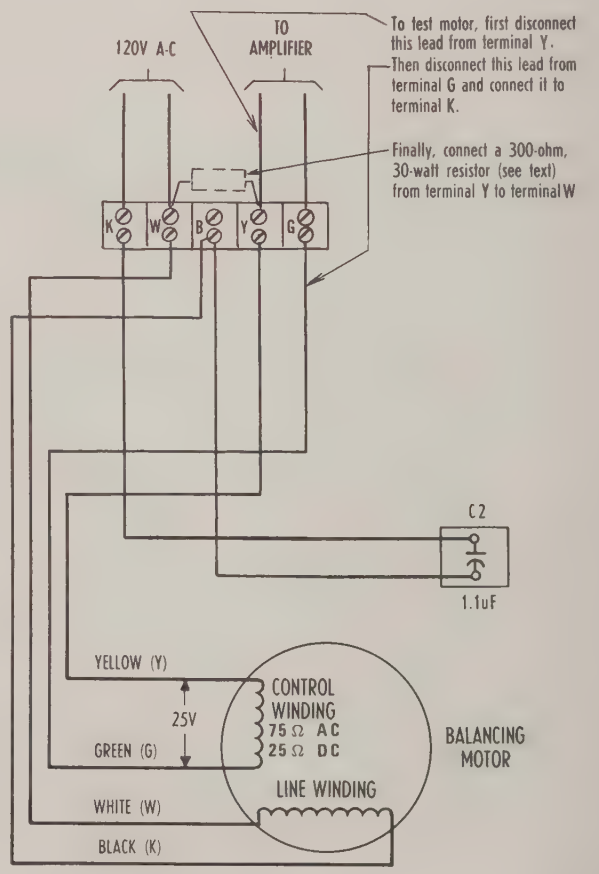


Fig. J1—Connections to balancing motor terminal board for checking balancing motor.

TABLE J1

SYMPTOM	RECOMMENDED CHECKS AND REPLACEMENTS
1 Instrument is completely inoperative including chart motor or motors.	Replace fuse. If new fuse blows immediately, refer to 3 below. If fuse is good, check line voltage across terminals L1 and L2 of instrument terminal board.
2 Line supply and fuse are good, but there is no balancing action.	Examine amplifier, range card, and power supply connectors for contacts that may not be making contact. Check terminal boards for loose screws. Replace amplifier with one known to be good. Test all measuring circuit wiring for continuity.
3 Fuse blows when replaced.	Turn off main power switch, chart motor switch if one is present, and all other optional switches. Check power circuit wiring for possible shorts. If none are found, replace fuse and turn on power switches one at a time until fuse blows. Trouble is probably in the circuit that was turned on last. If fuse blows when the amplifier is turned on, isolate the balancing motor from the amplifier by disconnecting the balancing motor leads from the terminal board. If a new fuse still blows, trouble is in the amplifier; if not, trouble is in the balancing motor. Test for shorts between all motor leads and case ground. If the fault cannot be easily repaired, replace the defective part with a known good one.
4 Response is sluggish and/or dead band is excessive (see Section H).	Adjust damping and gain controls on amplifier. With instrument turned off, manually rotate balancing motor shaft using balancing motor worm. The shaft should turn easily over the entire span and there should be no binding or backlash (play) in the system. Replace amplifier with a known good one.
5 Operates erratically, oscillates, or overshoots balance point.	Check and adjust amplifier gain and damping. Check connections to range card (including range card connector for bent contacts), terminal boards, and primary element.
6 Operation appears normal but scale reading is in error.	Check regulated power supply output voltage using a reference potentiometer. Check calibration of primary element. Check instrument calibration.

probes to pins #8 and #10 (see Fig. L8) on the amplifier plug-in connector. With the gain control set to the maximum clockwise position, the measuring pointer should run upscale or downscale, depending upon the polarity of the test leads. Reversing the test leads should cause the measuring pointer to run in the opposite direction.

If the balancing motor does not operate, it indicates that the trouble is in the amplifier. Refer to Section K. If the amplifier and balancing motor operate properly, the trouble is in the measuring circuit since, as shown in Fig. J2, this is the last major section remaining.

TROUBLESHOOTING MEASURING CIRCUIT

If preceding tests have isolated the fault to the measuring circuit, proceed with troubleshooting according to the steps outlined below. A typical wiring diagram of the measuring circuit is shown in Fig. J2.

(1) Measure the dc voltage across the potentiometer circuit at the regulated power supply, pins #1(+) and #3(—) of the power supply plug-in connector, Fig. L8. This voltage should be approximately 1 volt. See also Section L, Regulated Power Supply, Checking and/or Adjusting.

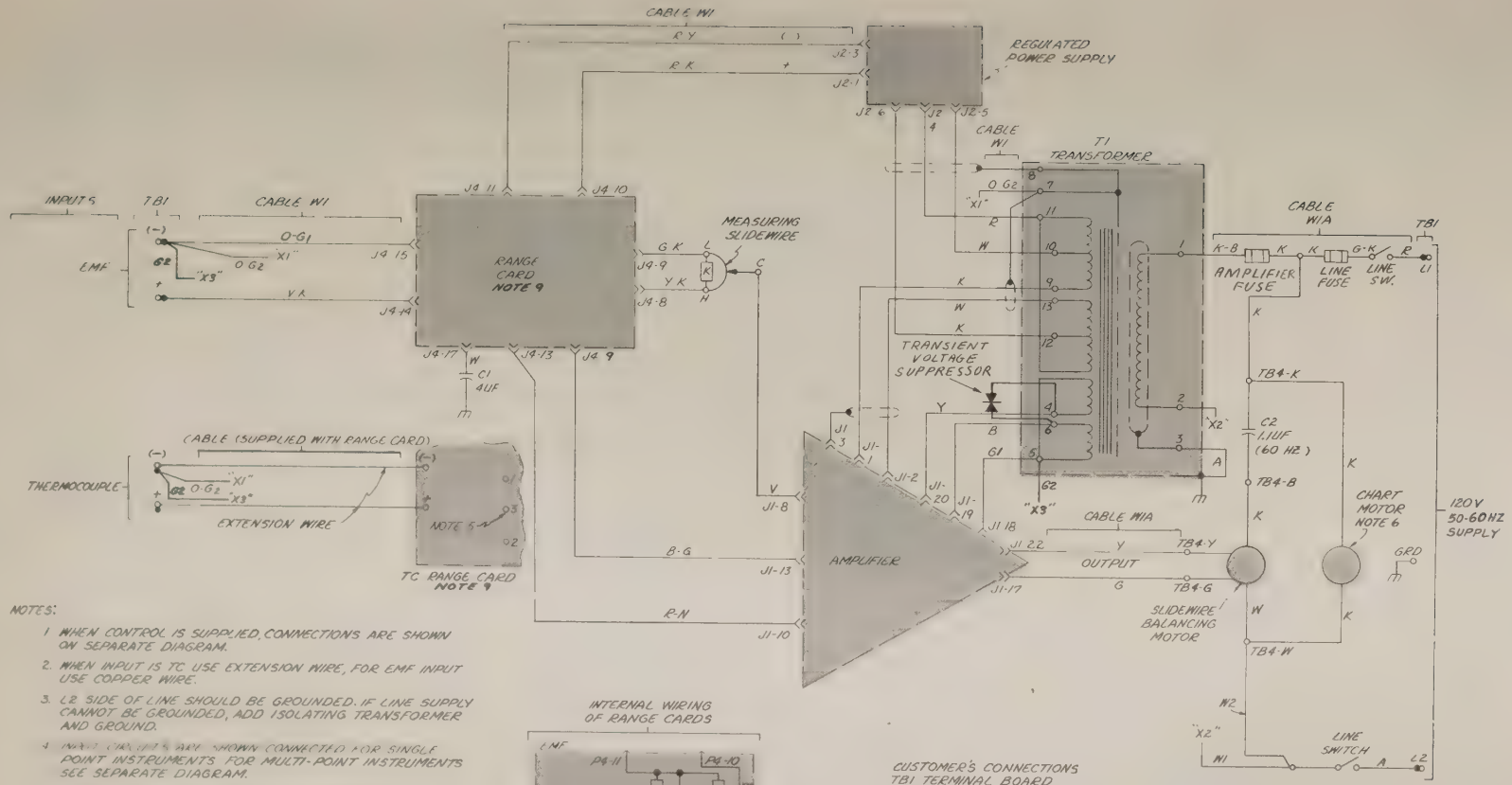
(2) Check continuity through the measuring slidewire and its contacts. On instruments having one or more compensator rheostats, also check continuity through tests parts.

(3) Test the 4 μF input circuit capacitor or substitute another for it, if this has not already been done.

(4) Remove the range card and susbtitute a spare card of the same type. If this restores correct operation, the faulty range card must be replaced.

TROUBLESHOOTING CABLES

Figs. J2 and J3 are typical schematic wiring diagrams of the Speedomax instrument. Fig. J2 includes the measuring circuit, Fig. J3 the cable routing diagram. Diagrams supplied with the instrument will be more or less similar to these depending upon recorder requirements.



NOTES:

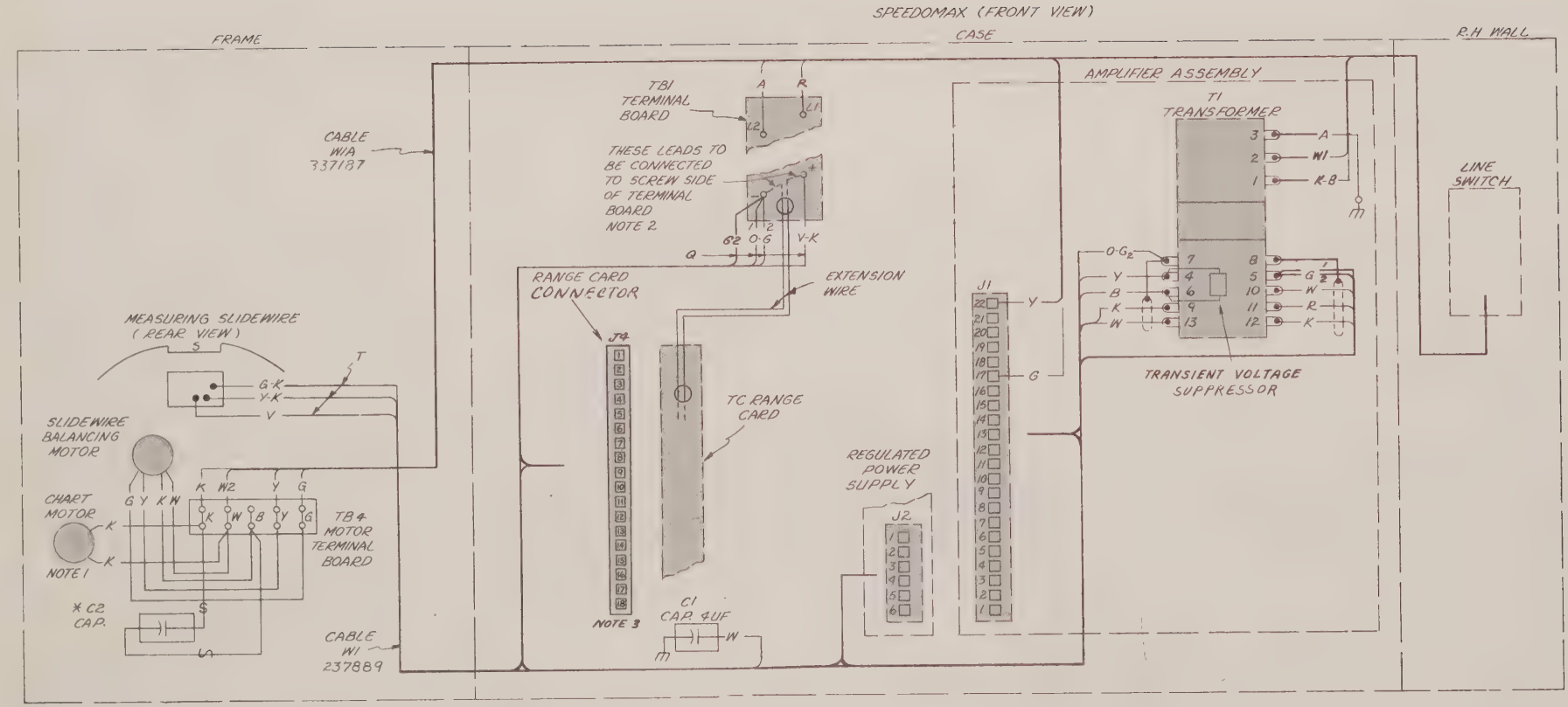
1. WHEN CONTROL IS SUPPLIED, CONNECTIONS ARE SHOWN ON SEPARATE DIAGRAM.
2. WHEN INPUT IS TC USE EXTENSION WIRE, FOR EMF INPUT USE COPPER WIRE.
3. L2 SIDE OF LINE SHOULD BE GROUNDED. IF LINE SUPPLY CANNOT BE GROUNDED, ADD ISOLATING TRANSFORMER AND GROUND.
4. INDIVIDUAL CIRCUITS ARE SHOWN CONNECTED FOR SINGLE POINT INSTRUMENTS. FOR MULTI-POINT INSTRUMENTS SEE SEPARATE DIAGRAM.
5. THERMOCOUPLE RANGE CARD HAS PROVISION FOR INPUT FAILSAFE OPERATION:
   A NO FAILSAFE; TERMINALS 1, 2 & 3 ARE LEFT OPEN.
   B UPSCALE; JUMPER WIRE IS CONNECTED BETWEEN TERMINALS 2 & 3.
   C DOWNSCALE; JUMPER WIRE IS CONNECTED BETWEEN TERMINALS 1 & 3.
6. CHART MOTOR IS OMITTED ON INDICATOR INSTRUMENTS.
7. ZERO SHIFT SWITCH, IF SUPPLIED, IS MOUNTED ON RANGE CARD ASSEMBLY.
8. INSTRUMENT IS SUPPLIED WITH EITHER TC AND/OR EMF RANGE CARDS AS SPECIFIED ON RECORDER SPECIFICATION.
9. WHEN THE RANGE CARD CONNECTOR HAS NUMERALS AND LETTERS, THE LETTER ADJACENT TO EACH NUMBER IS ELECTRICALLY COMMON. EXAMPLE 9 E K.

COLOR CODE	
K - BLACK	Y - YELLOW
W WHITE	A - GRAY
G - GREEN	V - VIOLET
R - RED	P PINK
B BLUE	S SLATE
N BROWN	T TAN
O ORANGE	

THERMOCOUPLE EXTENSION WIRE TABLE								
THERMOCOUPLE COMBINATION	EXTERNAL TO INSTRUMENT							INTERNAL OF INSTRUMENT
	DUPLEX				SINGLE COND			
	+	+		OVERALL	+			+
	COPPER CONST TYPE T	COPPER B	CONST A	B	COPPER B	CONST B-B	COPPER W-G	
	IRON CONST TYPE J	IRON N	CONST A	K	IRON M	CONST M-N	IRON W-K	CONST
	CHROMEL CONST TYPE E	CHROMEL N	CONST A	N	CHROMEL N	CONST N-B	CHROMEL W-Y	R-Y
	CHROMEL ALUMEL TYPE K	CHROMEL Y	ALUMEL B	Y	CHROMEL Y	ALUMEL P-Y	COPPER W-G	
	PLAT RHOD PLAT TYPE S OR R	COPPER K	ALLOY R	G	COPPER A	ALLOY R-K	COPPER K-G	ALLOY R-G
* THERMOCOUPLE WIRE USED AS EXTENSION WIRE								

DE5943

Fig. J2—Schematic wiring.



T INDICATES THREE TIGHTLY TWISTED WIRES

" INSULATING TUBING

* C2 = 1.6 UF 023692 FOR 50 HZ
1.1 UF 023689 FOR 60 HZ

Q INDICATES FOUR TIGHTLY TWISTED WIRES.

NOTES:

1. FOR USE WITH INDICATORS OMIT CHART MOTOR
2. ON MULTI POINT INSTRUMENTS, THE EXTENSION WIRE IS NOT TERMINATED ON TB1 TERMINAL BOARD. SEE SEPARATE DIAGRAM FOR PROPER CONNECTIONS
3. WHEN THE RANGE CARD CONNECTOR HAS NUMERALS AND LETTERS, THE LETTER ADJACENT TO EACH NUMBER IS ELECTRICALLY COMMON. EXAMPLE 9 & K.

COLOR CODE	
K - BLACK	Y - YELLOW
W - WHITE	A - GRAY
G - GREEN	V - VIOLET
R - RED	P - PINK
B - BLUE	S - SLATE
N - BROWN	T - TAN
O - ORANGE	

THERMOCOUPLE EXTENSION WIRE TABLE

THERMOCOUPLE COMBINATION		EXTERNAL TO INSTRUMENT					INTERNAL OF INSTRUMENT	
		DUPLEX			SINGLE COND.			
+	−	+	−	OVERALL	+	−	+	−
COPPER CONST. TYPE T		COPPER B	CONST. R	B	COPPER B	CONST R-B	COPPER W-G	CONST R-Y
IRON CONST. TYPE J		IRON W	CONST. R	K	IRON W	CONST. R-Y	IRON W-K	
* CHROMEL CONST TYPE E		CHROMEL V	CONST. R	N	CHROMEL Y	CONST R-B	CHROMEL W-V	
CHROMEL ALUMEL TYPE K		CHROMEL Y	ALUMEL R	Y	CHROMEL Y	ALUMEL R-Y	COPPER W-G	
PLAT. RHOD PLAT. TYPE S or R		COPPER K	ALLOY R	G	COPPER K	ALLOY R-K	COPPER K-G	ALLOY R-G

* THERMOCOUPLE WIRE USED AS EXTENSION WIRE

Fig. J3—Cable routing diagram.

DE5944

PART II — SERVICING AND TROUBLESHOOTING . . . . .

Section K — AMPLIFIER TROUBLESHOOTING

This section describes the testing and servicing procedures to be followed when the checks of Section J indicate amplifier trouble. The tests are for the 444508 or 444509 amplifier only. For those instruments equipped with a solid-state moderate impedance amplifier or with tube-type amplifier, refer to separate directions supplied with the instrument.

TEST EQUIPMENT

A volt-ohmmeter is required for checking ac and dc voltages and resistance values. It should have 20,000-ohm-per-volt impedance on the dc voltage ranges and 1000-ohms-per-volt impedance on the ac voltage ranges since the voltages given in this book are those obtained with a meter having these impedances. The Simpson Model 260 Multimeter has the required characteristics. If a lower impedance voltmeter is used in measuring voltages across high resistance circuits, lower readings must be expected, and conversely.

For checking capacitors, a capacitor tester may be substituted for the volt-ohmmeter.

A cable assembly (L&N Part No. 139265) is available that permits checking of the amplifier while energized. The cable assembly consists of a plug-in connector into which the amplifier can be plugged at one end and a printed-circuit card which plugs into the connector of the removed amplifier. Cable length between connectors is approximately three feet. An alligator clip, wired to the printed-circuit card, is also provided. This clip must be connected to a grounded part of the case during amplifier testing. The printed-circuit card has two finger holes in it to facilitate its installation and removal. A label marked UP indicates that that end must be installed in the up position (cable comes out from bottom), because the card itself is not polarized and hence can be installed upside down.

When the amplifier is energized from the cable assembly, care must be exercised in handling it to avoid contact with hazardous voltages since both 120 and 25 V 60 Hz voltages are present. In addition, take precautions not to set the amplifier on any metallic surface or on tools of any sort that might result in shorting of components, particularly from the foil side.

GENERAL TEST INFORMATION

Do not proceed with the tests of this section until the simple checks described in Section J have been carried out.

Caution: Turn off all power to the instrument before removing or installing the amplifier and/or other components.

Exercise care in handling the amplifier by not attempting to flex it or to apply undue forces to any of the mounted components; to do so may lead to intermittent or complete circuit failure.

Most troubleshooting checks can be performed using the ohmmeter method, as outlined in Table K1. Use these figures as a guide only. Remove the amplifier to get at the points indicated.

For voltage tests remove the amplifier cover and then turn on power to the recorder. See Fig. K1 for voltage check points. With cover off and amplifier energized, avoid bodily contact with amplifier components. When replacing the amplifier cover, note that the two nylon screws go on top.

Capacitor Testing—Capacitors of high value (0.1 μF and larger) are to be tested with the volt-ohmmeter set to its highest ohms range, or with a capacitor tester. When taking resistance readings across a capacitor or in any circuit where a capacitor is across the voltohmmeter the meter needle should deflect when first connected and then return to the value of resistance which may be involved in the circuit. This deflection indicates the capacitor is good and will take a charge. If the deflection does not occur, it will indicate that the capacitor is open-circuited and should be replaced. If the meter needle deflects and remains below the value of the parallel circuit resistance, the capacitor is short-circuited or is leaky and should be replaced.

Note: If the capacitor is an electrolytic type, some leakage is to be expected. Also, the positive (+) ohmmeter lead must be connected to the positive side of the capacitor. Otherwise, the resistance reading will be low even if the capacitor is good.

On polarized tantalum capacitors, polarity should be observed. It should be understood that these capacitors can be damaged by reversing the leads of the ohmmeter.

Replacing Components—When the amplifier has been found to be faulty, it should be replaced. Replacement of faulty parts on this unit is not recommended.

When replacing a faulty power transformer the new part and wiring should conform to the original arrangement. Use as little solder as possible when soldering, but be sure that a satisfactory connection is made. See Caution note above.

Test Procedure—It is suggested that the various steps in amplifier troubleshooting be performed in the sequence given in Tables K1 through K3.

For voltage measurements the line voltage is to be 120 volts ac. The tolerances on all voltages and resistances given in Tables K1 and K2 are as indicated. See also General Test Information above.

TABLE K1 — AMPLIFIER *RESISTANCE* TESTS

STEP	TEST INSTRUCTIONS** (POINTS)	(+)	(−)	NORMAL INDICATION OHMS RESISTANCE (±20%)	PROBABLE CAUSE OF ABNORMAL INDICATION (FAULTY COMPONENT(S))
1	T1*	Grd	Y Lead	∞	C9
	"	"	O "	∞	T1
	"	"	W "	∞	
	"	O-Lead	Y "	700	
	"	R- "	N "	300	
	"	G- "	N "	300	
2	Q1	B	C	1000	Q1
		B	E	1000	
3	Q2	G	D	1400	Q2
		G	S	1400	
4 5 6	Q3 Q4 Q5	B	C	900	Q3
		B	E	900	
7	Q6	B	C	800	Q6
		B	E	800	
8	Q7	C	B	600	Q7
		E	B	400	
		E	C	4000	
9	Q8	C	B	900	Q8
		E	B	900	
10	Q9	B	C	600	Q9
		B	E	400	
		C	E	3000	
11	Q10	B	C	800	Q10
		B	E	800	
12	A1 Emitter				
		Grd	$Q1_E$	0	Open A1
		"	$Q2_S$	500	
		"	$Q3_E$	0	
		"	$Q4_E$	0	
		"	$Q5_E$	0	
13	VR1			800 (Forward) 15000 (Reverse)	VR1
14	VR2, VR3			900 (Forward) (Reverse)	VR2, VR3

*Gain switch in LOW position. **Ohmmeter on R x 100 range.

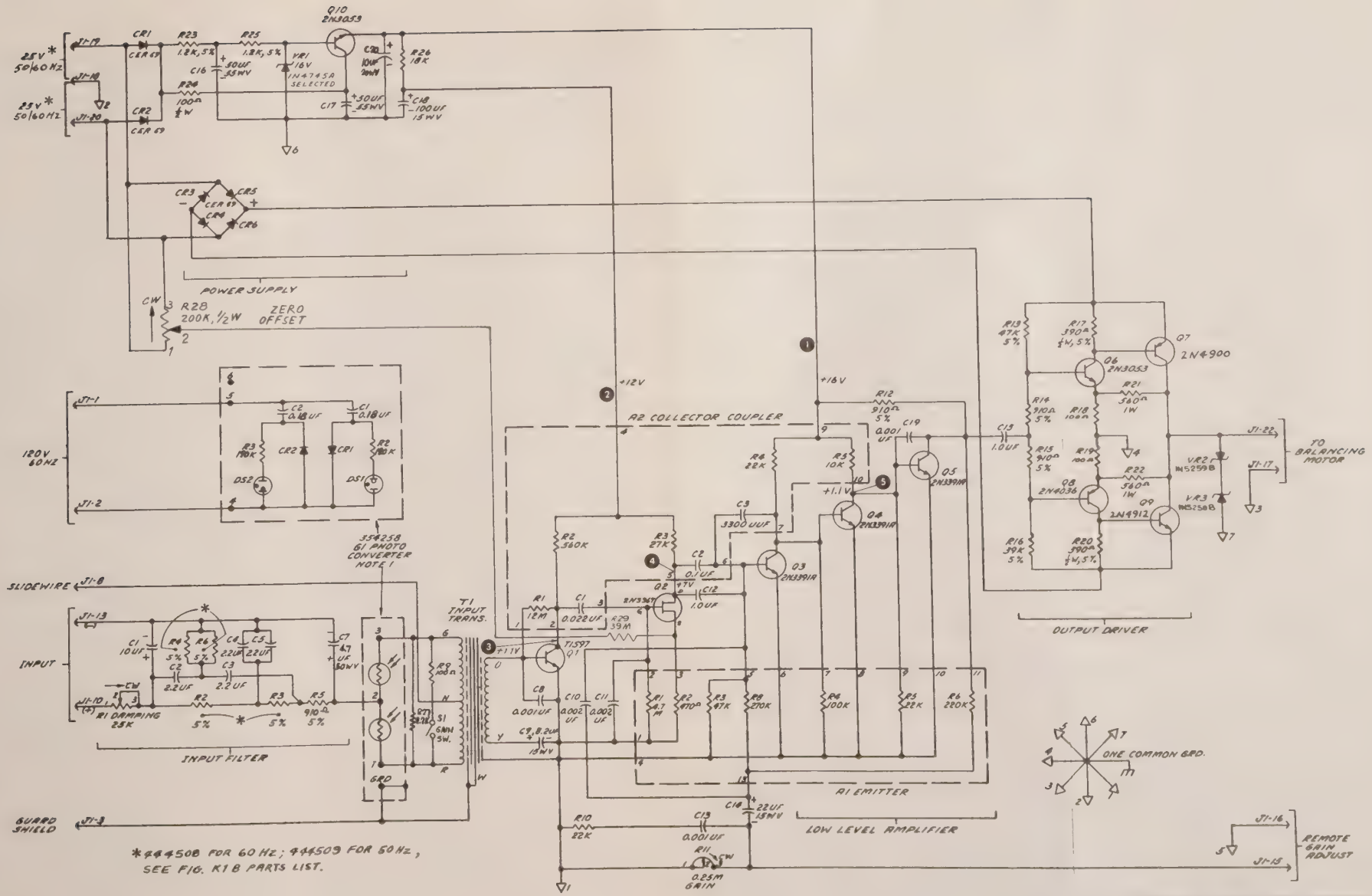
TABLE K2 — POWER TRANSFORMER, GAIN AND DAMPING CONTROLS, AND PHOTOCONVERTER *RESISTANCE* TESTS

STEP	TEST INSTRUCTIONS		NORMAL INDICATION (RESISTANCE IN OHMS ±10%)	PROBABLE CAUSE OF ABNORMAL INDICATIONS (FAULTY COMPONENTS)
1 Power Transformer Test	Amplifier and Power Supply Removed. All Power Disconnected. Insulator Removed Secondary Pin Layout 7 8 4 5 6 10 9 11 13 12	Points 4 to 5 5 to 6 4 to 6 10 to 11 9 to 10 12 to 11 13 to 12 9 to 11 13 to 11 9 to 13 11 to 7 11 to 5 11 to 2 11 to Grd. 1 to 2 (L1 to L2 with Line Switch ON and fuse IN)	 4 4 8 35 18 35 18 53 53 106 ∞ ∞ ∞ ∞ * *	 Power Transformer Line switch or fuse
2 Gain Control Test	Amplifier Removed	Points Across R11	Resistance varies smoothly from 0 to 250KΩ when turned from CW to CCW position	Gain control R11
3 Damping Control Test	Amplifier Removed	Points Across R1	Resistance varies smoothly from 0 to 25KΩ when turned from CCW to CW position	Damping Control R1
4 G1 Photo Converter Test	Amplifier Energized Cover Removed	Points Across Converter Red wire from input transformer to low end side of R5 Green wire from input transformer to low end side of R5	 1000 to 2000 1000 to 2000	 Photo Converter

*For transformer marked NTC, R = 70 ohms ± 10%.
For transformer marked 352----, R = 30.5 ohms ± 10%.

TABLE K3 — POWER TRANSFORMER *AC VOLTAGE* TESTS

STEP	TEST INSTRUCTIONS		NORMAL INDICATION AC VOLTAGE (±10%)	PROBABLE CAUSE OF ABNORMAL INDICATION (FAULTY COMPONENT(S))
		Points		
Power Transformer	Amplifier	On Amplifier Plug-in Connector, Starting from Bottom to Top		Power Transformer
	Cover	1 to 2	120V	
		18 to 19	25V	
	Removed	18 to 20	25V	
		On Power Supply Plug - in Connector, Starting from Top to Bottom		
		4 to 5	40V	
		4 to 6	40V	
		See Fig. L8		



NOTES:
1. PIN MARKINGS ON 61 PHOTO CONVERTER ARE FOR WIRING IDENTIFICATION PURPOSE ONLY. MARKINGS DO NOT APPEAR ON PHOTO CONVERTER.
2. UNLESS OTHERWISE SPECIFIED:
   ALL RESISTORS ARE ±W,
   ALL RESISTORS ARE 10%

COLOR CODE	
K - BLACK	Y - YELLOW
W - WHITE	A - GRAY
G - GREEN	V - VIOLET
R - RED	P - PINK
B - BLUE	S - SLATE
N - BROWN	T - TAN
O - ORANGE	

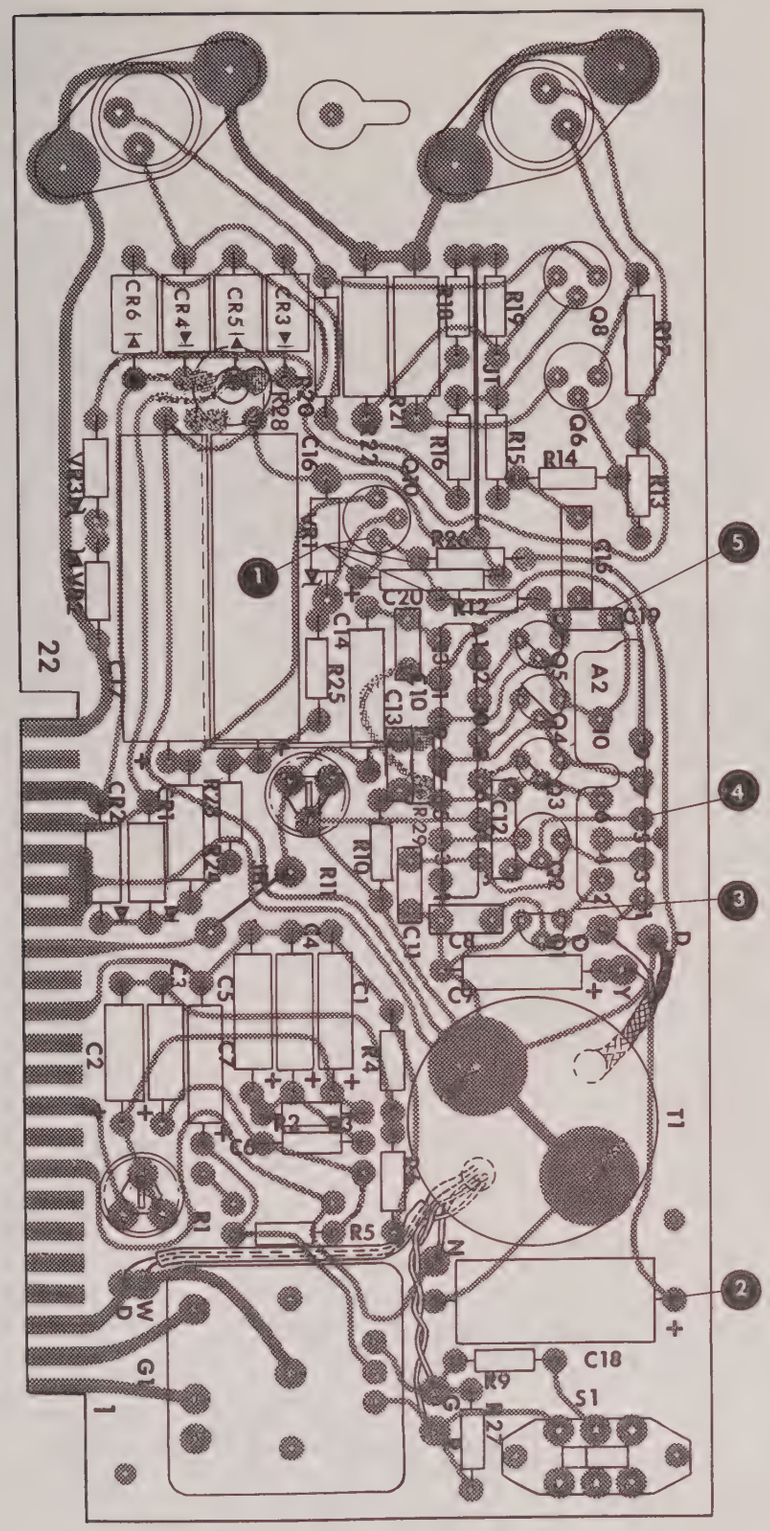
THERMOCOUPLE EXTENSION WIRE TABLE

THERMOCOUPLE COMBINATION	EXTERNAL TO INSTRUMENT						INTERNAL OF INSTRUMENT	
	DUPLEX			SINGLE COND				
+	−	+	−		+	−	+	−
COPPER CONST TYPE T	COPPER T	CONST T	B	COPPER T-B	CONST T-B	COPPER T-B	CONST B-Y	
IRON CONST TYPE J	IRON W	CONST R	K	IRON W-R	CONST R-W	IRON W-R		
CHROMEL CONST TYPE E	CHROMEL V	CONST R	H	CHROMEL V-R	CONST R-G	CHROMEL B-V		
CHROMEL ALUMEL TYPE K	CHROMEL Y	ALUMEL R	Y	CHROMEL Y	ALUMEL R-Y	COPPER W-G		
PLAT.-RHOD TYPE S or R	COPPER R	ALLOY R	G	COPPER R	ALLOY R-G	COPPER R-G	ALLOY R-G	

① THERMOCOUPLE WIRE USED AS EXTENSION WIRE

Fig. K1A—Schematic wiring of 444508 or 444509 solid-state amplifier. Encircled numbers relate to Fig. K1B.

DE5937



E5938

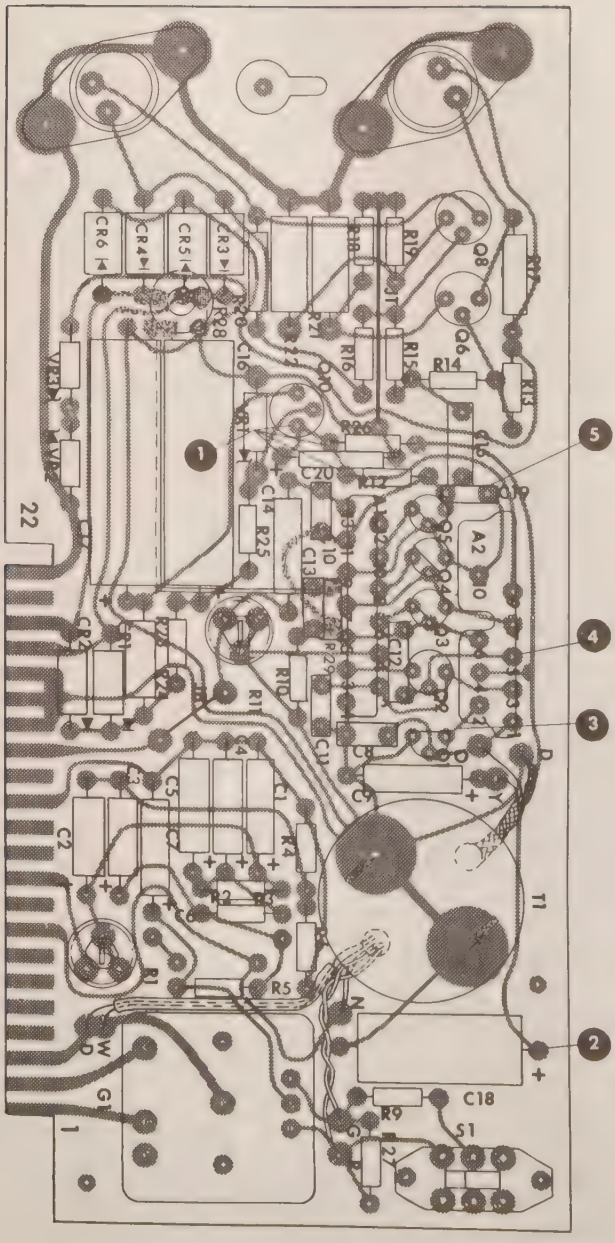
Fig. K1B—444508 or 444509 solid-state amplifier and parts list, as noted. Encircled numbers relate to Fig. K1A.

AMPLIFIER PARTS

COMPONENT	DESCRIPTION	L&N PART NO.
--	Printed Circuit Board	144508
--	Label (444508)	287507
R1	Potentiometer, 25 kΩ	013482
□R2, R3, R4, R6	Resistor, 1.2 kΩ ±5%, 1/4 W	311650
▲R2, R3, R4, R6	Resistor, 1.5 kΩ ±5%, 1/4 W	011926
R5, R12, R14, R15	Resistor, 910 Ω ±5%, 1/4 W	311652
R9, R18, R19	Resistor, 100 Ω ±10%, 1/4 W	011994
R10	Resistor, 22 kΩ ±10%, 1/4 W	011771
R11	Potentiometer, 0.25 MΩ	013483
R13	Resistor, 47 kΩ ±5%, 1/4 W	311734
R16	Resistor, 39 kΩ ±5%, 1/4 W	311735
R17, R20	Resistor, 390 Ω ±5%, 1/2 W (2)	011734
R21, R22	Resistor, 560 Ω ±10%, 1 W	011251
R23, R25	Resistor, 1.2 kΩ ±5%, 1/4 W	311650
R24	Resistor, 100 Ω ±10%, 1/2 W	011132
R26	Resistor, 18 kΩ ±10%, 1/4 W	311312
R27	Resistor, 2.2 kΩ ±10%, 1/4 W	011927
R28	Potentiometer, 200 kΩ	013472
R29	Resistor, 39 MΩ ±10%, 1/4 W	311704
C1, C20	Capacitor, 10 µF ±10%, 20 V	023462
C2, C3, C4, C5	Capacitor, 2.2 µF ±10%, 35 V	023368
C7	Capacitor, 4.7 µF ±5%, 50 V	023582
C8, C13, C19	Capacitor, 0.001 µF, 500 V (3)	023097
C9	Capacitor, 8.2 µF ±10%, 15 V	023279
C10, C11	Capacitor, 0.002 µF, 500 V (2)	023248
C12, C15	Capacitor, 1.0 µF, 25 V (2)	023415
C14	Capacitor, 22 µF ±10%, 15 V	023303
C16, C17	Capacitor, 50 µF, 70 V (2)	023332
C18	Capacitor, 100 µF, 15 V	023561
CR1 thru CR6	Rectifier, Silicon Diffused Junction (CER69, 1N4816, TS2) (6)	057028
VR1	Zener Diode, 16 V ±5%, 1 W (1N4745A selected)	057141
VR2, VR3	Zener Diode, 39 V, 1/2 W (1N5259B) (2)	057209
Q1	Transistor, (T1S97)	188188
Q2	Transistor, (2N3367)	188187
Q3, Q4, Q5	Transistor, (2N3391A or SM8749) (3)	188165
Q6, Q10	Transistor, (2N3053) (2)	188173
Q7	Transistor, (2N4900)	188259
Q8	Transistor, (2N4036) SS9326	188226
Q9	Transistor, (2N4912)	188228
A1	Imbedment	144324
A2	Imbedment	144432
--	Insulator (3)	034872
G1	Photo Conductive Converter	354258
JT, JT1	Sol. Cu. Silvered Teflon (W)	Purchase locally
JB	Sol. Cu. TN.	Purchase locally
T1	Transformer	019411
--	Insulation Sleeving - 1-7/8 Lg.	11.5-3
--	Silicone DC-4 Grease	18.19
S1	Switch	032421
--	Bracket (Heat Sink)	273552
--	Cover Assembly	267533
--	Stop Screw	504312
--	Lock Nut (#8-32 Br. Hex NP)	--
--	Round Stud (2)	061765
--	Spacer (2)	061629
Screw	1/4 x 6-32 Bind. Hd. Nylon (2)	004979
Screw	3/16 x 6-32 Bind. Hd. Br. Cr. P. (2)	--
Screw	3/8 x 4-40 Bind. Hd. Br. Cr. P. (4)	--
Screw	1/4 x 6-32 Bind Hd. Br. Cr. P. (2)	--
Nut	#4-40 Br. Hex NP (4)	--
Nut	#3-48 Br. Hex NP (2)	--
Washer	#6 KLLW (2)	--
Washer	#3 KLLW (2)	--
Washer	#1104 S.P.L.W. (4)	--

□ *60 Hz (444508)*

▲ *50 Hz (444509)*



E5938

Fig. K1B –444508 or 444509 solid-state amplifier and parts list, as noted. Encircled numbers relate to Fig. K1A.

AMPLIFIER PARTS

COMPONENT	DESCRIPTION	L&N PART NO.
--	Printed Circuit Board	144508
--	Label (444508)	287507
R1	Potentiometer, 25 kΩ	013482
□R2, R3, R4, R6	Resistor, 1.2 kΩ ±5%, 1/4 W	311650
▲R2, R3, R4, R6	Resistor, 1.5 kΩ ±5%, 1/4 W	011926
R5, R12, R14, R15	Resistor, 910 Ω ±5%, 1/4 W	311652
R9, R18, R19	Resistor, 100 Ω ±10%, 1/4 W	011994
R10	Resistor, 22 kΩ ±10%, 1/4 W	011771
R11	Potentiometer, 0.25 MΩ	013483
R13	Resistor, 47 kΩ ±5%, 1/4 W	311734
R16	Resistor, 39 kΩ ±5%, 1/4 W	311735
R17, R20	Resistor, 390 Ω ±5%, 1/2 W (2)	011734
R21, R22	Resistor, 560 Ω ±10%, 1 W	011251
R23, R25	Resistor, 1.2 kΩ ±5%, 1/4 W	311650
R24	Resistor, 100 Ω ±10%, 1/2 W	011132
R26	Resistor, 18 kΩ ±10%, 1/4 W	311312
R27	Resistor, 2.2 kΩ ±10%, 1/4 W	011927
R28	Potentiometer, 200 kΩ	013472
R29	Resistor, 39 MΩ ±10%, 1/4 W	311704
C1, C20	Capacitor, 10 µF ±10%, 20 V	023462
C2, C3, C4, C5	Capacitor, 2.2 µF ±10%, 35 V	023368
C7	Capacitor, 4.7 µF ±5%, 50 V	023582
C8, C13, C19	Capacitor, 0.001 µF, 500 V (3)	023097
C9	Capacitor, 8.2 µF ±10%, 15 V	023279
C10, C11	Capacitor, 0.002 µF, 500 V (2)	023248
C12, C15	Capacitor, 1.0 µF, 25 V (2)	023415
C14	Capacitor, 22 µF ±10%, 15 V	023303
C16, C17	Capacitor, 50 µF, 70 V (2)	023332
C18	Capacitor, 100 µF, 15 V	023561
CR1 thru CR6	Rectifier, Silicon Diffused Junction (CER69, 1N4816, TS2) (6)	057028
VR1	Zener Diode, 16 V ±5%, 1 W (1N4745A selected)	057141
VR2, VR3	Zener Diode, 39 V, 1/2 W (1N5259B) (2)	057209
Q1	Transistor, (T1S97)	188188
Q2	Transistor, (2N3367)	188187
Q3, Q4, Q5	Transistor, (2N3391A or SM8749) (3)	188165
Q6, Q10	Transistor, (2N3053) (2)	188173
Q7	Transistor, (2N4900)	188259
Q8	Transistor, (2N4036) SS9326	188226
Q9	Transistor, (2N4912)	188228
A1	Imbedment	144324
A2	Imbedment	144432
--	Insulator (3)	034872
G1	Photo Conductive Converter	354258
JT, JT1	Sol. Cu. Silvered Teflon (W)	Purchase locally
JB	Sol. Cu. TN.	Purchase locally
T1	Transformer	019411
--	Insulation Sleeving - 1-7/8 Lg.	11.5-3
--	Silicone DC-4 Grease	18.19
S1	Switch	032421
--	Bracket (Heat Sink)	273552
--	Cover Assembly	267533
--	Stop Screw	504312
--	Lock Nut (#8-32 Br. Hex NP)	--
--	Round Stud (2)	061765
--	Spacer (2)	061629
Screw	1/4 x 6-32 Bind. Hd. Nylon (2)	004979
Screw	3/16 x 6-32 Bind. Hd. Br. Cr. P. (2)	--
Screw	3/8 x 4-40 Bind. Hd. Br. Cr. P. (4)	--
Screw	1/4 x 6-32 Bind Hd. Br. Cr. P. (2)	--
Nut	#4-40 Br. Hex NP (4)	--
Nut	#3-48 Br. Hex NP (2)	--
Washer	#6 KLLW (2)	--
Washer	#3 KLLW (2)	--
Washer	#1104 S.P.L.W. (4)	--

□ *60 Hz (444508)*

▲ *50 Hz (444509)*

Section L — MISCELLANEOUS ITEMS

NULL-BALANCE MEASURING SYSTEM

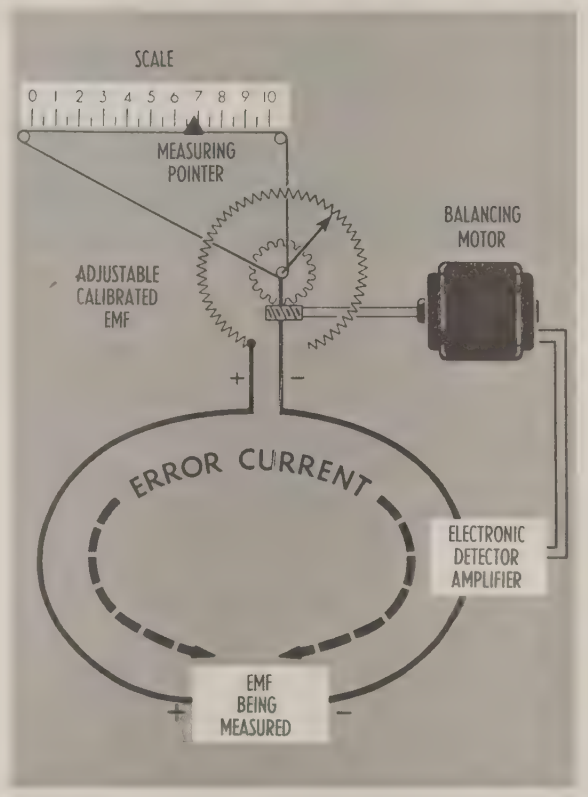
The Speedomax instrument comprises an automatic null-balance measuring system in which balance is accomplished through the use of an electronic amplifier. The essential parts of such a system are, (1) the null-balance measuring circuit, (2) the null detector-amplifier, (3) the balancing motor and linkage, and (4) the display system, i.e., recording and/or indicating devices.

Fig. L1 illustrates the general plan of the system. In this instance — measurement of emf — the measuring circuit consists of an adjustable calibrated emf connected to oppose the emf being measured. If these two emf's are not equal, an "error" or unbalance current flows as shown and is detected by the input circuit of the amplifier.

After amplification, the error signal is applied to the reversible balancing motor which then works through the mechanical linkage to adjust the calibrated emf. The system is sensitive to the direction of error current so that the motor always adjusts the calibrated emf in the proper direction to reduce the magnitude of the error current. The motor continues to drive until the error current is so small that the amplified signal will no longer produce motor rotation. Amplification is great enough that this occurs when the error current is substantially zero and the calibrated emf differs by only a negligible amount from the emf being measured. A null or balance condition then exists.

While adjusting the calibrated emf, the motor also drives the display system. Pointer position therefore directly indicates the calibrated emf and hence the emf being measured. The indicator scale may be marked in terms of emf, or in terms of temperature or other variable producing the measured emf.

Although the foregoing illustration applies particularly to emf measurement, the basic method is equally applicable to measurement of resistance. In both instances a precise, known quantity is continuously and automatically adjusted to be equal to the quantity being measured.



E4565

Fig. L1 — Schematic illustration of null-balance method applied to emf measurement

SPEEDOMAX H CHARACTERISTICS

Dead Band — The dead band of a null-balance instrument is defined as the range through which the measured quantity can be varied without causing response, i.e., balancing action. Dead band is conveniently expressed in percent of span. For instruments with millivolt spans of 1 mV or greater, the dead band rating is 0.15% or less of the span.

Accuracy — Instrument accuracy is defined as the maximum difference which will exist between the instrument reading and the true value of the measured quantity under rated operating conditions. Accuracy is commonly expressed in percent of span.

Rated accuracy of standard instruments is ±0.3% of span for spans of one millivolt and over, having a suppression ratio (SR) of 2 to 1 or less. For suppression ratios greater than 2 to 1, the accuracy is ±[0.3 + 0.1 (SR-2)]%. The suppression ratio is the ratio of the electrical equivalent of the smaller end scale value to the electrical span; it does not include zero.

For example, on a span of +20 to +30 millivolts or −30 to −20 millivolts, the suppression ratio is $\frac{20}{30-20} = 2$. The accuracy figure includes errors due to dead band, to tolerances in calibrated circuit components (precision resistors, slidewire, regulated power supply), and to tolerances in mechanical components of the balancing and indicating systems. It does not, however, include inaccuracies in the thermocouple or other primary element.

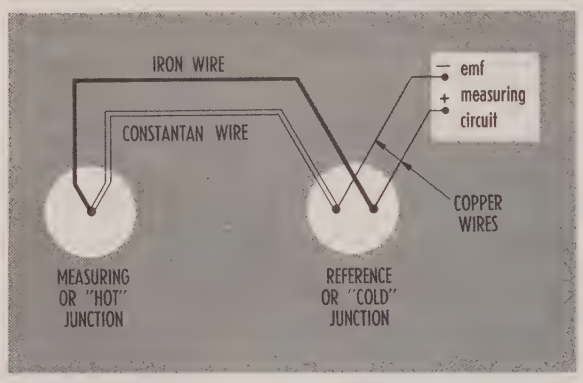


Fig. L2 — Basic thermocouple circuit.

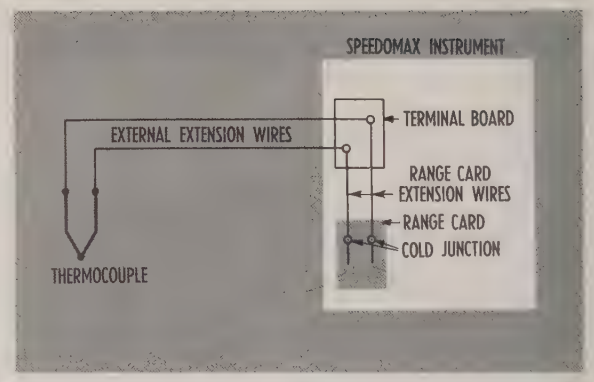


Fig. L3 — Extension of thermocouple cold junction to range card.

Effect of Source Resistance — Very high resistance in the source of the measured emf has two effects on the performance of a potentiometer instrument. First, it tends to increase dead band because the IR drop across the source resistance reduces the voltage at the amplifier input terminals. Second, it makes for slower instrument response since source resistance is effectively part of the damping resistance and, when very large, will cause overdamping. The maximum source resistance which may be used without noticeable effect on either rated accuracy or dead band is 2000 ohms.

Step Response Time — This is the time required for the instrument to come to rest at the new balance point after an instantaneous change in the measured quantity. The rated step response time of standard instruments may be either 1 second or 5 seconds, as ordered.

THERMOCOUPLE CIRCUIT

The Thermocouple — For electrical measurement of temperature, the thermocouple is the most frequently used primary element. A thermocouple consists of two dissimilar metal wires joined together by twisting, compression, welding, etc., to form a measuring or "hot" junction at one end. The opposite ends of the thermocouple wires are connected to an instrument which measures the output emf of the couple. Fig. L2 shows this arrangement for a thermocouple composed of iron and Constantan (a copper-nickel alloy).

As shown in Fig. L2, copper wires are ordinarily used to connect the emf measuring circuit to the thermocouple wires. This results in two additional connections of dissimilar metals, i.e., an iron-copper connection and a Constantan-copper connection. These two connections are always close to each other so that they are at the same temperature. Together, they form the so-called "cold" or reference junction of the thermocouple.

Extension Wires — In order to provide reference junction compensation, as will be described, the cold or reference junction must be located at the instrument range card. This is accomplished by the use of extension wires to connect the thermocouple to the instrument terminal board. In addition, internal extension wires are used to further connect from the terminal board to the range card. Fig. L3 indicates this arrangement. Note that the extension wires serve to actually *extend* the couple to the range card. These wires must therefore have thermoelectric characteristics similar to those of the couple. Usually the extension wires are composed of the same materials as the thermocouple wires themselves. In some cases, however, wires of different composition but similar thermoelectric properties are employed.

RANGE CARDS/EMF FAILSAFE/FAILSAFE ERROR

The range card is a printed-card assembly, with cover, approximately 2″ x 3″ x 1″, as shown in Fig. L4. It plugs into a receptacle in the instrument case and is held in place by the receptacle. The two mounting screws provide additional clamping action when required.

Range cards are available for the two types of standard measuring circuits, namely potentiometer and Wheatstone bridge. Potentiometer circuits include thermocouple and emf. Thermocouple circuits cover most types of thermocouples presently available, while emf circuits cover such primary elements as load cells, pH electrodes, and Rayotubes (radiation detectors). Wheatstone bridge circuits apply to resistance elements such as Thermohm detectors.

The card shown in Fig. L4 is for a thermocouple measuring circuit. Extension wires provided with the card vary with the type of thermocouple, and are connected to designated terminals in the measuring instrument.

The circuits on the range cards are generally planned so that the range of the instrument can be changed by removing one range card and inserting another with no further change in the wiring. This procedure applies

not only for changing from one range to another with the same type measuring circuit, but also in some cases, to changing from one type of measuring circuit to another so long as the scale and chart paper, where applicable, are also changed. For example, it applies in the case of Rayotubes when the required compensator dial assembly is added to an emf measuring circuit. It applies also to the use of thermocouple or emf cards interchangeably or directly in a Rayotube range card instrument. Finally, it applies to changing the range of multiple-point recorders so long as the range card used is that designated for the type of thermocouples used.

Most cards other than thermocouple, emf, and Rayotube, however, are not interchangeable with each other.

The range of most special range card instruments can be changed in the same manner provided the type of measuring circuit is not changed.

Range cards and the scales with which they are used are available as follows:

CIRCUIT	SCALE
Millivolt	Standard Reversed Standard or zero center
Rayotube	Standard
Thermocouple	Standard
Resistance (Thermohm)	Standard

(1) Standard Range

This is the form most commonly used. The zero or low limit of the range is at the left end of the scale and the upper limit of the range is at the right end.

(2) Reversed Range

Reversed ranges are opposite standard ranges, i.e., the zero or low limit (most negative) is at the right end of the scale and the upper limit (most positive) is at the left end. See Reversed-Range EMF Range Cards, this section.

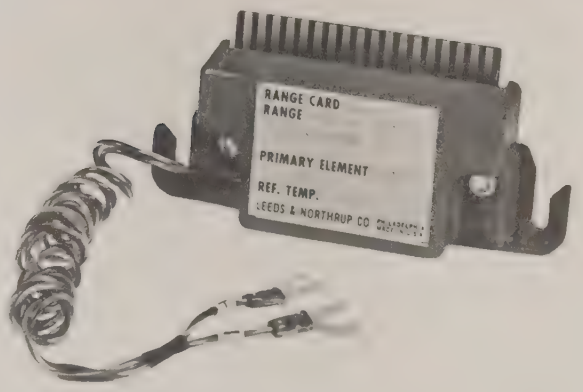
(3) Standard Range for Rayotube

Range cards for Rayotube instruments are furnished with the lower limit of the range on the left end of the scale and the upper limit of the range on the right end. In addition, the cards are provided with an integrally mounted two-position switch. This switch serves to make an instrument more versatile by permitting Rayotubes of different output to be used with the same instrument. For example, in the 1-5 position, the millivoltage compensator range is 1 to 5 millivolts, while in the other position, the millivoltage compensator range is 5 to 25 mV.

Thus by merely changing scales and chart paper, a Rayotube instrument can be used with most standard Rayotubes manufactured by L&N.

(4) Standard or Zero-Center Range

The standard-or-zero-center range cards are provided with an integrally mounted two-position switch



E.3202

Fig. L4 — Range card (for thermocouple measuring circuit).

marked POS A (for position A) and POS B (for position B). With the switch in the POS B position, the zero is at the left end of the scale. With the switch in the POS A position, the zero is at the center of the scale. In earlier range cards, ZERO LEFT replaces POS B and ZERO CENTER replaces POS A.

There are range card installations, however, which call for minor wiring changes, depending upon intended range card usage. These changes are made either on the card itself or to the recorder input. Range card installations requiring such changes comprise:

(1) Reversed-range emf range cards.

(2) Range cards that include input failsafe and/or reference junction compensation.

EMF/TC Reversed Ranges — In general, ***standard*** ranges are those that cause the pointer of an instrument to be driven upscale (from left to right) as the input variable becomes ***more positive***. ***Reversed*** ranges are just the opposite. They cause the pointer to be driven upscale as the input variable becomes ***less positive*** (more negative). Examples of reversed ranges are +10 to 0, −10 to −20, etc.

An instrument furnished with a reversed range has the same measuring and motor circuits as an instrument with a standard range, except the balancing motor and slidewire connections are reversed as noted below. Therefore, standard range cards may be used.

For example, to convert a standard range instrument to a reversed range instrument, simply reverse the connections to the measuring slidewire (Y−K and G−K), as well as reversing the Y and G leads of the balancing motor at the motor terminal block. Conversely, to convert a reversed range instrument to a standard instrument, reverse the connections outlined above. Then plug in the required range card. A new scale may be necessary unless the one presently in use can be appropriately re-marked.

TABLE L1

Range Card Type	CONNECTIONS				Fig.
	Failsafe*		Ref. Junction Comp.*		
	Upscale	Downscale	Standard	Remote	
Thermo-couple	• (2 to 3)	o (1 to 3)	Connect where indicated by □ (from b to c)	Connect where indicated by ■ (from a to b & c to d)	L5A
Rayotube	• (2 to 3)	—	—	—	L5B

* Connect one only

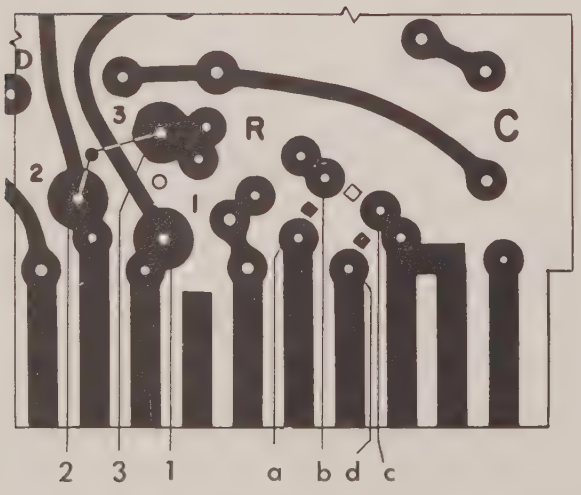
Range Cards That Include Input Failsafe and/or Reference Junction Compensation — The installation of wiring connections (jumpers) as outlined below may be made by the factory at the time of order processing of the instrument or range card, when specified, or by the user. When not specified the cards are furnished unconnected. Connections are then left to the user. Connections can be made or changed as required in accordance with Table L1 and Figs. L5A and B.

On thermocouple range cards only, the failsafe feature is provided with jacks instead of solder connections. Thus, in making connections or reconnections for this feature, simply insert the wire jumper provided, in the required holes. Make certain that the wire jumper does not come in contact with any circuit foil.

Where connections or reconnections are to be made by soldering, the following items are recommended to avoid damaging the card:

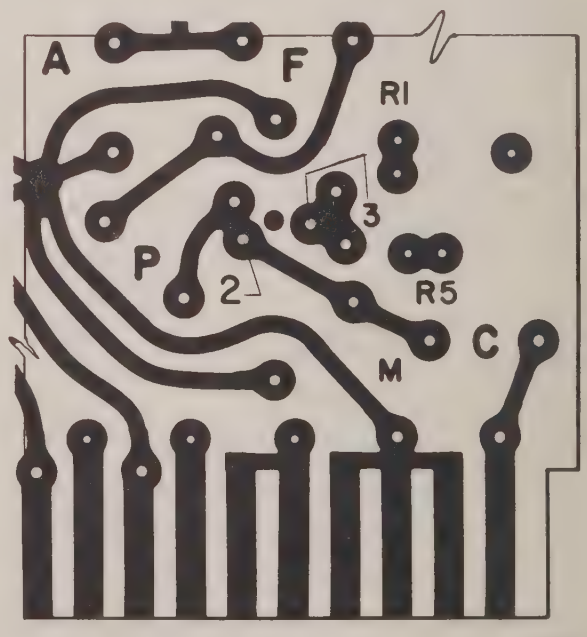
(1) A soldering iron not larger than 25 watts capacity,
(2) #20 gage or smaller solid, tinned copper wire,
(3) Resin core solder.

(1) Range Card With Failsafe Feature



E3511

Fig. L5A — Section of thermocouple range card showing connections for input failsafe and reference junction compensation. See Table L1.



E3513

Fig. L5B — Section of Rayotube detector range card showing connections for input upscale failsafe. See Table L1.

Failsafe is a safeguard feature which causes the pointer of the instrument to travel upscale or downscale upon failure (opening) of the primary element. The direction of travel is usually effected through appropriate wiring connections on the card itself.

All standard thermocouple and Rayotube detector range cards have provision for input failsafe on the printed circuit and are supplied with the input failsafe resistor (R) mounted. On thermocouple range cards, either upscale or downscale failsafe can be provided by installing the jumper in accordance with Table L1. On Rayotube detector range cards, only upscale failsafe can be provided when the jumper is installed in accordance with Table L1. No provision is available for Rayotube detector downscale failsafe.

(2) Reference Junction Compensation

Reference junction compensation provides correction for any change in thermocouple reference or cold junction temperature. This may be effected locally in the recorder or remotely.

Local use is considered standard. In this case, the thermocouple extension wires are normally brought directly into the measuring instrument. Connections for local reference junction compensation are listed under Standard in Table L1.

Remote reference junction compensation is generally used where the pairs of thermocouple extension wire from the area of measurement to the measuring instrument would be long and/or many. This feature permits the use of copper wires between these points, and only a single pair of thermocouple extension wires instead of separate pairs of extension wires for each couple. Connections for remote reference junction compensation are listed under Remote in Table L1.

For remote reference junction compensation applications, in addition to the range card change, external wiring changes are also required, as indicated in Fig. L6. To make the external wiring changes, proceed as follows:

(1) Disconnect the range card extension wires from the INPUT positive (+) and negative (—) terminals and reconnect them to any available unused terminals on the terminal board.

(2) Connect extension wires from the remote junction box to the same terminals as those to which the range card extension wires were connected in step 1. Observe polarity in making these connections and be sure that the extension wire used corresponds to the type of range card and thermocouples being used.

(3) Connect copper wire from the recorder INPUT terminal board to the switch assembly, and from there to the remote junction box, as indicated. The switch assembly may be a manually operated selector-type switch or it may be a remote switching unit such as supplied with Speedomax H and W multipoint instruments. In the latter case, supplementary directions are included with the instrument.

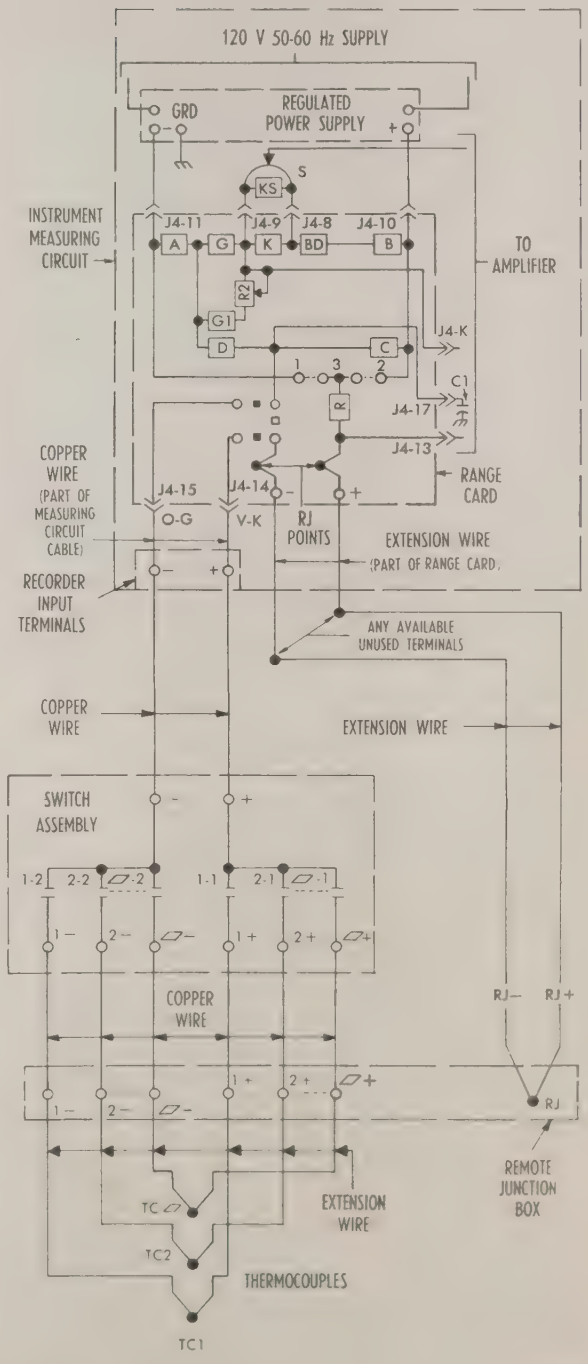
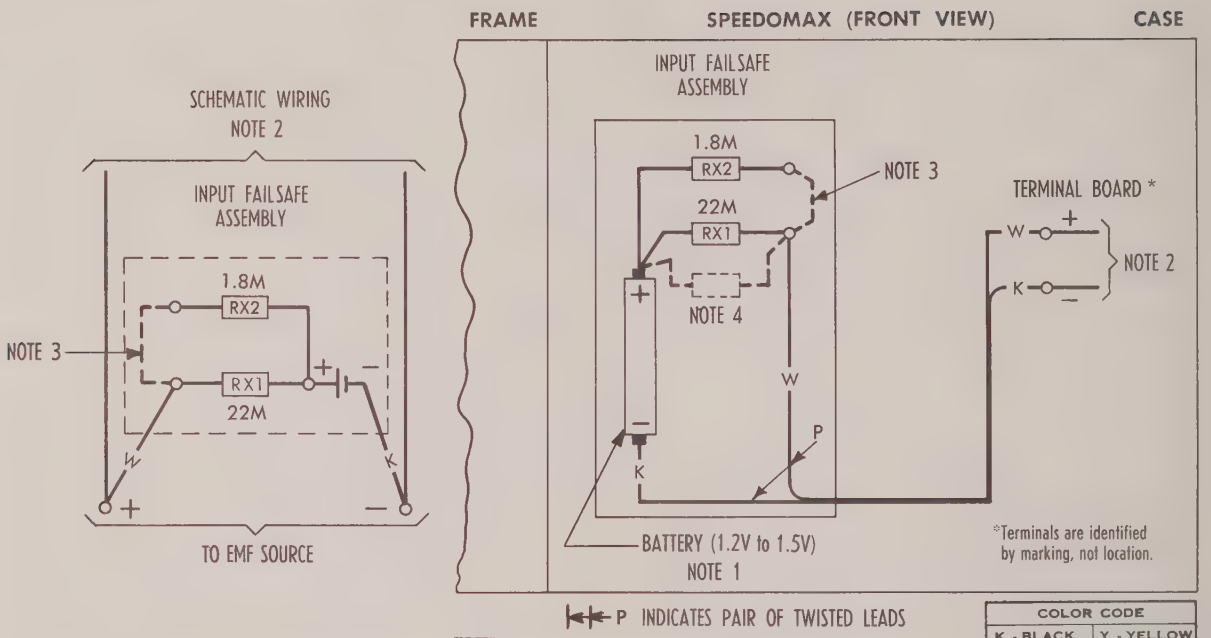


Fig. L6 — Remote reference junction compensation connections



COLOR CODE	
K - BLACK	Y - YELLOW
W - WHITE	A - GRAY
G - GREEN	V - VIOLET
R - RED	P PINK
B - BLUE	S - SLATE
N - BROWN	T - TAN
O - ORANGE	

E4786

NOTES

1. Battery is shown connected for upscale failsafe operation. For downscale operation reverse battery. Any type battery can be used (1.2V to 1.5V).
2. For remainder of typical input circuit, see Fig. J2.
3. Tinned copper wire. Connect as shown dotted for spans greater than 10MV and less than 100 MV.
4. Add resistor .15M(¼W) L&N part no. 011769 across resistor RX1 for span 100 MV or greater.

Fig. L7 — EMF input failsafe.

EMF FAILSAFE

Instruments furnished for emf measurements have no provision for input failsafe on the range card. Instead, a separate input failsafe assembly (L&N Part No. 145061) is available, either for factory installation or for installation in the field. The assembly consists of a battery in series with one or more resistors connected as indicated in Fig. L7; it is mounted on a panel in the rear interior of the instrument case and wired across the input terminals as shown. Since the emf source resistance is usually quite small compared to the failsafe resistors, the voltage appearing across the emf input due to the failsafe battery is also quite small during normal operation. However, if the emf input circuit fails, i.e., becomes open-circuited, the full battery voltage is impressed across the instrument input terminals, causing the pointer and/or pen to be driven off scale. The direction of travel depends upon the polarity of the failsafe battery.

Note that for spans greater than 10 millivolts and less than 100 millivolts a jumper is added which reduces the overall resistance of both resistors, and for spans of 100 millivolts or greater a 0.15 megohm resistor (L&N Part No. 011769 [1/4 W]) is connected across resistor RX1. Thus, if the range card in the instrument is changed to a higher or lower millivolt span, the failsafe resistance must be changed accordingly.

FAILSAFE ERROR

The error caused by either the thermocouple range card or emf battery-type failsafe feature is negligible provided the external resistance, i.e., the resistance of the thermocouple or emf source plus its leads, is small. The error may be of consequence, however, in narrow span instruments used with thermocouple or emf inputs having long input leads and/or high source resistance. Factory calibration is made on the basis of zero ohm external resistance. For external resistance other than zero ohm, the error increases somewhat proportionately — from zero error for zero ohm to approximately 0.2% of span error for 200 ohms.

The error occurs in the direction of failsafe action and can either be taken into consideration or compensated for by shifting the measuring slidewire. The amount of shift can be determined by first noting the pointer position with the failsafe circuit open, i.e., jumper or battery removed, then replacing the jumper or battery and shifting the slidewire until the pointer reaches its original position. When making this adjustment, the instrument should be allowed to warm up for one-half hour and the input must remain constant.

Speed of response of failsafe action is usually somewhat slower than the step response of the instrument. For example, for a 1-second instrument it is approximately 3 seconds.

THE REGULATED POWER SUPPLY

General Information — The regulated power supply, shown mounted in a recorder in Fig. L8, converts normal ac line power to dc power for use in the potentiometer circuit. Its dc output current will remain at a fixed, constant value despite fluctuations in line voltage between the limits of 107 and 127 volts, variations in frequency from 48 to 64 Hz, and changes in ambient temperature from 16° to 75° C. The magnitude of this dc current is of critical importance, for in passing through the potentiometer circuit it generates the reference voltage with which all unknown voltages are compared.

Checking and/or Adjusting — There is a particular setting for each 099089 power supply such that it will provide a precise 10 mA dc current to the potentiometer measuring circuit. A small rheostat, mounted on the card and marked POWER SUPPLY OUTPUT ADJ on the cover, can be adjusted to furnish the required 10 mA current for circuit resistances between 101 and 109 ohms. Proper adjustment has been made at the factory on each instrument, and the unit should require no immediate attention on the part of the user.

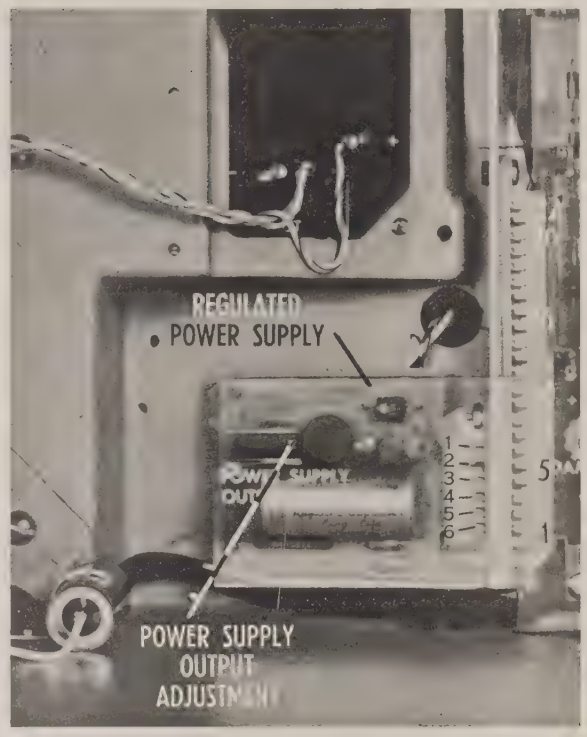
The circuit resistance is determined by the range card and will almost universally be 105 ohms. The interchangeability of range cards is directly dependent upon the known and fixed supply voltage. The power supply therefore should not be adjusted to any other terminal voltage than that for which its load circuit was designed. In the case of the range card instrument with a 105-ohm circuit resistance, this voltage is 1.05 volts ±0.05%.

The foregoing does not apply to resistance bridge measuring circuits where the power supply terminal voltage does not directly affect circuit accuracy or range card interchangeability. In this case a different power supply—099155 or equivalent—may be used which will provide a current to the bridge, adjustable between 1 mA and 10 mA. The terminal voltage, however, will depend upon the particular circuit and supply setting, but should normally be between 1.5 and 3.0 volts.

The power supply should be checked and possibly readjusted whenever any field change or inadvertent damage to electrical components has occurred.

To check the 099089 power supply, use a precision potentiometer with a millivolt output range of at least 1090 millivolts. Some Leeds & Northrup potentiometers suitable for making this measurement include the (1) 7556 Six-dial Potentiometer, (2) 7554 Type K4 Universal Potentiometer, and (3) 8687 Portable Volt Potentiometer. (See Table H1).

With the instrument warmed up for at least 15 minutes, temporarily turn off the power on-off switch. Then remove the cover from the amplifier and turn the power back on, allowing for a minimum continuous warmup time of 5 minutes. Be careful not to touch components or wiring on either card. Using test leads with probe ends, contact pins 1 (+) and 3 (—) on the power supply side of the plug-in connector (not on the amplifier side).



E5945

Fig. L8 — Regulated power supply. Remove amplifier cover to gain access to pin connections shown.

See Fig. L8. Adjust the output by turning the Power Supply Output Adj. rheostat until the potentiometer indicates 1.05 V, ±0.05%. This voltage should provide the required 10 mA current through the range card. Then turn off the power again and replace the cover, making sure that the nylon screws go on top and the metal screws at the bottom.

To check the 099155 power supply, follow the same procedure outlined above for the 099089 except use a suitable voltmeter instead. It should be possible to adjust the output from 0.25 to 2.5 volts for a standard 250-ohm range card.

Instrument calibration should be made as outlined in Section H *after* the regulated power supply has been checked and/or adjusted, since the zero or end scale point may not be the same for every range card.

Maintenance — As has been stated, any future changes to the electrical circuitry of the instrument such as the installation of new parts or repair work, will necessitate re-executing the adjustment and calibration procedure described above. As a part of this procedure it may be helpful to check the power supply with a voltmeter at its output terminals (#1 (+) and #3, Fig. L8); but there are no checks to be made on the internal circuitry of the unit itself. If the unit is defective, it must be replaced.

PART III — TECHNICAL INFORMATION . . . . .

Section M — TWO-POSITION CONTROL

Two-position control, also called "on-off" or "open-shut" control, is the simplest type of automatic control, and is suitable for many processes where the control requirements are not critical. It gets its name from the fact that the device which regulates the process input, e.g., a fuel valve in the case of a heating process, can assume only two positions regardless of the value of the variable being controlled. In two-position control, the process input is automatically set to one limit when the controlled variable falls below a predetermined level, and is automatically set to the other limit when the controlled variable rises above a predetermined level.

The switches on the Speedomax instrument can be used to provide two-position control of the variable being measured. The switches may operate a valve, contactor, damper, or other device controlling the process input.

Depending upon the user's needs, the two-position control may be of either the single point or the differential-gap type as follows:

TWO-POSITION SINGLE POINT CONTROL

In this arrangement, the process input is changed from maximum to minimum and from minimum to maximum at the same value of the controlled variable. Fig. M1 illustrates this control action in the case of a temperature control. Here it is assumed that a single low contact is used to turn on a heating element whenever temperature falls below the set point, and to turn off the element when temperature exceeds the set point.

In any process there is some delay or lag between a change in the input and the resultant change in controlled variable indicated on the measuring instrument. Consequently, as shown in Fig. M1, when heat is turned on, temperature continues to fall for a period before starting to increase. Similarly, when heat goes off, temperature continues to rise for a period before starting to decrease. This alternate overshoot and undershoot of the set point produces the cyclic temperature fluctuation shown. Such cycling is an inherent characteristic of two-position control.

The magnitude of the cyclic temperature swings, and hence the magnitude of the deviations from the set point, is directly related to the heat transfer characteristics and measuring lags of the particular process. Thus if the temperature measurement responds rapidly to changes in heat input, departure from the set point will be small. Conversely, where response is slow, substantial temperature deviations will result. This dependence of the control behavior upon process lags applies not just to heating processes, but to any type of process.

Fig. M2 illustrates the effect of process demand on two-position control. Curve (1) shows the same condition as Fig. M1; that is, temperature cycles evenly about the set point, heater on and off times being equal. For a higher process demand, i.e., more heat required to maintain a given temperature, the response is as

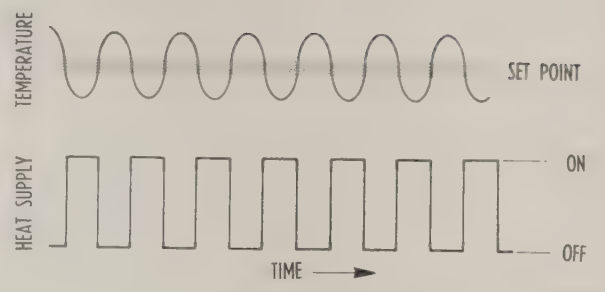


Fig. M1 — Two-position single point control action.

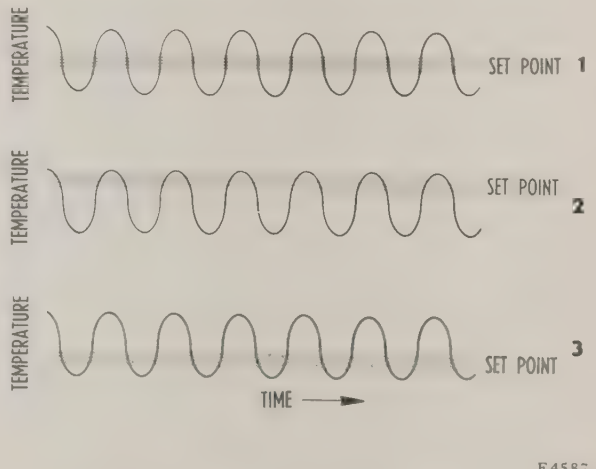


Fig. M2 — Effect of process demand on two-position control action.

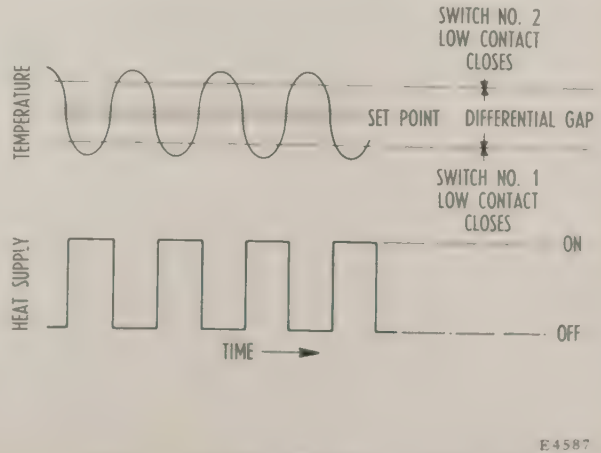


Fig. M3 — Two-position differential gap control action

shown by curve (2). Here the *on* time is greater, while the temperature cycles at a lower average value than in curve (1). Curve (3) shows these effects reversed for a lower process demand. In general, the ratio of on-time to off-time is proportional to demand, and the average is above or below the set point.

TWO-POSITION DIFFERENTIAL-GAP CONTROL

In this method of control, the process input is changed from maximum to minimum at one value of the controlled variable and from minimum to maximum at another value of the controlled variable. Fig. M4 is a schematic diagram of such a control arrangement. As shown, two switches are used, but only the low contact of each switch is connected into the circuit. These contacts operate auxiliary relay R which in turn controls the process input.

Switches No. 1 and No. 2 are set to operate at equal deviations of instrument reading below and above the set point, respectively. The difference between these two switch settings, measured in terms of scale units, is the differential gap.

Assume that the arrangement shown in Fig. M4 is to be used for controlling an electric heating process. Then the heater contactor coil is connected in series with the SR-2 front contact. When process temperature is below the setting of both switches, relay SR is energized and the SR-2 front contact is pulled in to turn heat on. At the same time, the SR-1 front contact is also closed. Thus relay SR is kept energized through its own SR-1 front contact and the L contact of switch No. 2, and heat remains on even after increasing temperature causes the L contact of switch No. 1 to open.

When temperature rises to the setting of switch No. 2, its L contact opens, thereby de-energizing the SR relay coil. This drops out the SR-2 front contact, turning heat off, and also opens the SR-1 front contact. The heat then remains off until decreasing temperature again operates switch No. 1, thus starting a new cycle.

Fig. M3 illustrates the control action provided by this circuit. It can be seen that the response is nearly identical with that of the single point control shown in Fig. M1. Because of the differential gap, it differs in two respects: (1) the magnitude of the cyclic temperature swings is greater, and (2) operation of the final control element (the contactor in this instance) is less frequent. In some applications where the final control element is a valve or power contactor, this reduced frequency of operation may be particularly desirable, and usually is the principal reason for using differential-gap control, despite the corresponding increase in deviation from the set point.

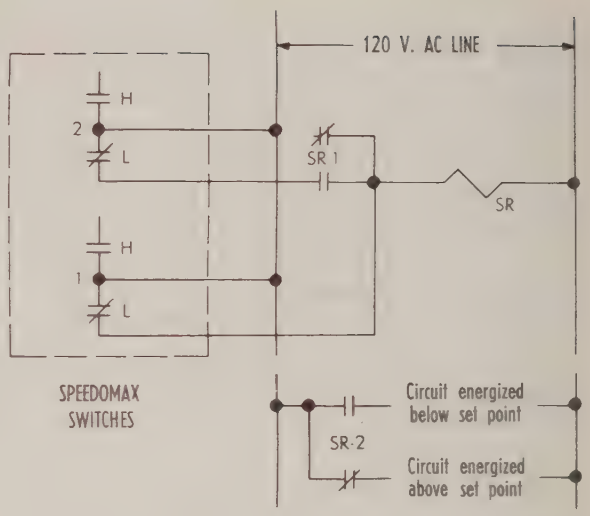


Fig. M4 — Schematic of two-position differential gap control circuit using two switches and an auxiliary relay.

In the preceding example, it was required to energize the final control element, i.e., the contactor, for low values of the measured variable. In some arrangements, however, reversed control action might be required, i.e., final control element energized for high instrument readings. This is done by connecting the final control element in series with the SR-2 back contact, Fig. M4.

APPENDIX IV

Section N — FIELD CHANGES AND OPTIONAL FEATURES

RANGE CHANGE

The Speedomax instrument can be easily converted to a new range of the same type simply by replacing the range card, indicating scale, and chart paper if a recorder.

Remove the old card, together with its leads, where applicable, as instructed in Section F, and install the new card. Replace the scale and check and adjust the alignment as instructed in Section H.

After making the range change, it is advisable to recheck the calibration of the instrument as instructed in Section H.

Also, if an emf instrument and the range card is changed to a different emf span, check Section L, EMF Failsafe, for possible change of the failsafe resistance value.

CHART TEAR-OFF DEVICE

This optional feature facilitates removal of used sections of chart with minimum paper loss. It is used on Model S instruments only. The device consists of a tear-off bar, and a reroll mandrel equipped with a take-up device. Instructions for chart installation and use of the tear-off device are given in Fig. N1.

CHART SPEED CHANGE

Several different chart speeds are available. It should be noted that to change from one chart speed to another it is necessary, in some instances, to change both the motor and motor pinion, or the motor or motor pinion only.

The items received from the factory indicate which must be replaced. The procedure for removing and replacing the chart motor and pinion is outlined in Section F, CHART MOTOR, Model S. Follow this procedure and replace the necessary parts with the new ones

OTHER OPTIONAL FEATURES

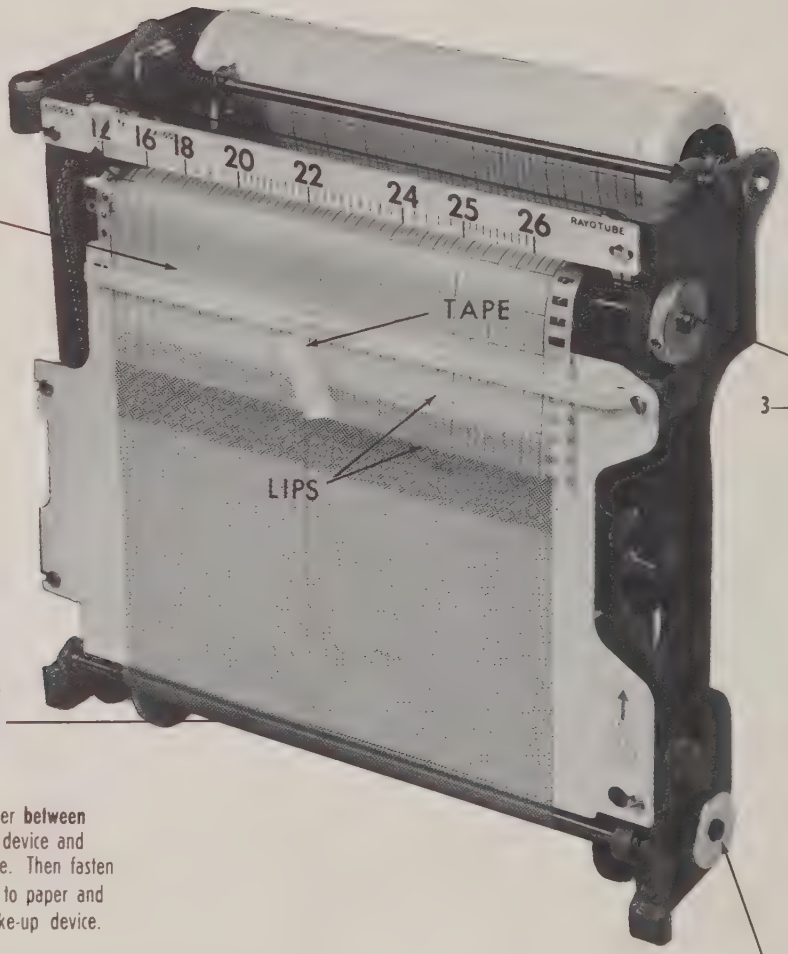
These features are covered either in separate directions or in drawings supplied with the instrument. Some of the more popular features available, besides those already described, include:

(a) Carrying handle, feet, and line cord
*(b) Chart motor switch
*(c) Mechanical indexing pen lifter
(d) Off-scale limit features
*(e) Writing table
*(f) Removable door with slip hinges
*(g) Double chart speeds
*(h) Fluorescent illumination
*(i) Indexing pen
(j) Rayotube filter circuit
(k) Signal light for power failure

* Model S only

Options (a), (c), (e), (f), (h), (i), and (k) are also supplied in kit form for field mounting on existing instruments. Note, however, that because of limited space, not all features desired can be included in a particular instrument. Therefore, before ordering any optional feature, consult the nearest L&N office stating the serial number and catalog number of the instrument for which the feature is to apply

1—Mount new chart roll according to steps 1, 2 and 3 of Fig. B9.



2—Carry paper **over** drive roll and **under** tear-off bar. Then tear paper off straight along lower edge of bar.

3—Now turn drive roll knob to advance paper about 1″ below tear-off bar.

5—Carry take-up device up **over** lower guide shaft as shown.

6—Place chart paper **between** lips of take-up device and **center** on device. Then fasten gummed tape to paper and lower lip of take-up device.

7—Turn reroll knob to place tension on chart paper. Chart is now ready for use.

8—To remove paper from reroll mandrel, turn reroll knob to release tension. Grasp chart at both edges and pull forward to unroll from mandrel. Detach tape and tear off chart along bar. Then repeat steps 3 to 7, so that chart is again ready for use.

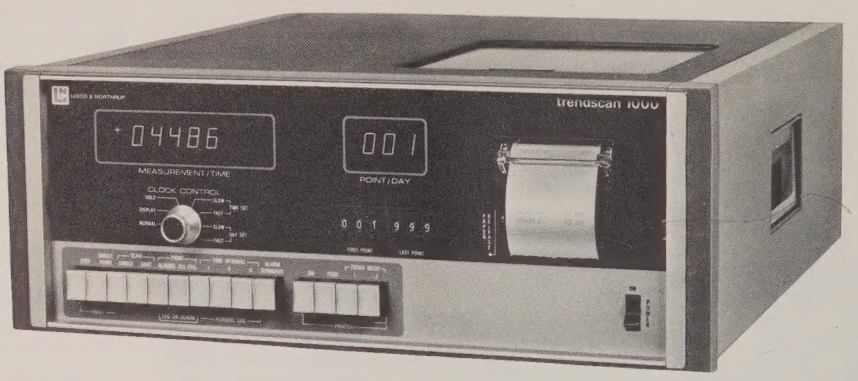
4—Pull this reroll knob out and mount reroll mandrel with take-up device between flanges. Keys of both flanges **must** engage slots in end of mandrel.

E4591,E4624

Fig. N1 — Use of chart tear-off device

NOTES

Leeds & Northrup's Trendscan 1000 Data Acquisition System



...lets you speed read your data with logging, trending and alarming up to 1000 points

Features

- **Scanning, alarming, logging up to 1000 points.**
- **3+ or 4+ digit measurements . . . Single or Multi-range.**
- **Linear and non-linear inputs . . . TC, RTD, V, mV, mA and contact closure.**
- **Easy programming . . . range selection, point skip, alarm commutation.**
- **Integral printer . . . ribbonless, non-impact, 21 alphanumeric columns.**
- **Unique Trend Mode . . . prints bar graphs (Trendbars) for trending or profiling.**
- **Full alphanumeric printing of legends, status and static data.**
- **Built-in clock.**
- **Six internal digit alarms . . . or 128 with external Trendscan Alarm Processor.**
- **Remote location of input switching assemblies . . . up to 3200 feet (1000 meters).**
- **Low thermal input switching relays . . . convenient isothermal input connectors.**
- **Self-test of each range . . . independent of inputs.**
- **Flexible input/output peripheral interface.**

The Trendscan 1000 Data Acquisition System provides a highly flexible means of scanning, alarming, trending and/or logging up to 1000 inputs—thermocouples, RTDs, transmitters, EMF signals, current signals and/or contact closures. Single ranges or multi-ranges (3) are available with 3+ or 4+ digit resolution. Multi-range units may include any combination of linear or non-linear signals including TC, RTD, mV, V, mA or contact closure.

A complete 20 point system can be provided in a single compact (7″ × 19″ × 22½″) chassis for bench use or rack mount. This includes two 10 point input switching relay cards with isothermal connectors (5 inputs per card for RTD)—basic point selection and scanning controls with point display—signal conditioning, A/D conversion, linearization and measurement display—an integral printer for data logging and a clock which provides system or real time with controls to initiate a periodic data log at intervals up to 8 hours.

INPUT SWITCHING When more than 20 inputs are needed, input switching relays and input connectors are supplied in Model 2701 Trendscan Input Frames which accommodate up to 10 input cards (100 inputs) per frame. Up to 10 frames can be supplied for 1000 inputs. These frames may be located up to 3200 feet (1000 meters) away from the Trendscan 1000 for convenient and economical installation near the input elements.

Point selection signals are supplied to each of the 2701 Input Frames through a 42 conductor matrix cable from the Trendscan 1000 where the point selection and scanning controls are located. A set of input signal leads for each range are connected between the 2701 Input Frame(s) and the 2700 Trendscan. No power connections are required for the Input Frames.

ALARMS Up to 6 bipolar digital alarms and a per point alarm programming feature are available. The Trendscan 1000 can be specified with 1, 2 or 3 internally mounted alarm modules, each with two independent alarms. A module has two sets of digital switches to set a 4 digit limit corresponding to the 4 most significant digits of the measurement. Each alarm limit has a separate sense switch for HI or LO limit, and a polarity select switch. One reset switch is provided on each module common to both alarms. Each alarm has an LED indicator and a SPDT output relay connected to screw terminals at the rear of the Trendscan.

When more than 6 alarms are required, the 2783 Trendscan Alarm Processor is available in place of the internal alarms for up to 128 different dual level alarms.

PROGRAMMING Following a very simple sequence, any one of up to 250 input points may be addressed and assigned to any one of three available ranges (except RTD ranges which are assigned in groups of 5 inputs). Any point may be skipped or assigned to any one, none or all of the 6 internal alarms. Points programmed for point skip do not cause a loss of time during the scan cycle.

Systems with more than 250 input points are programmed in a similar manner except that range, point skip and alarm assignments are made in groups of 5 points rather than on a per-point basis. All programming is stored in solid state memory (RAM) with a continuously charged battery back-up for 1000 hour program retention without line power.

LEEDS & NORTHRUP

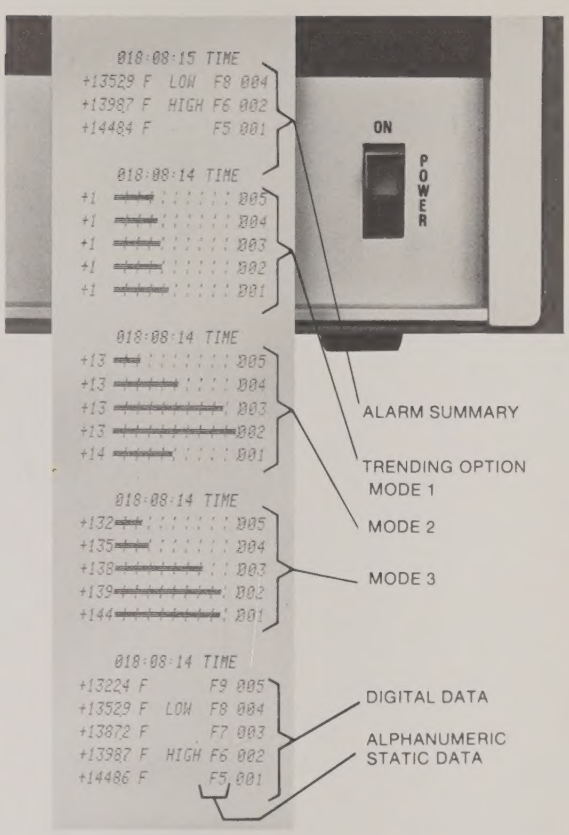
PRINTOUT Trendscan 1000 systems offer unique capabilities for data presentation. An integral ribbonless printer prints out point identification, optional 4 character static data, status reports on inputs (e.g. OPEN or OVLD) and alarms (e.g. HIGH or LOW), four or five digit presentation of measured variable with polarity and legend plus an independent line stating time of printout, all arranged in an orderly format. In addition, an exclusive Trend Mode feature is available which graphically presents the least significant digits in the measurement as a bar graph (Trendbar) preceded by a numeric printout of the most significant digit(s). Three modes of increasing resolution are available for the Trendbar graph in which 1, 2 or 3 of the most significant features are suppressed and printed out, and the next two digits are presented in the Trendbar format.

The three modes of digital suppression allow successively higher resolution with the Trendbar for critical analysis in analog form. Best resolution is achieved in Mode 3 which can be as high as 1 part in 40,000 on a 4+ digit instrument or 1 part in 4,000 on a 3+ digit instrument, depending on the total range selected.

Printout of any single point, group of points or all points, may be initiated either manually, in response to an alarm, or on a preset time interval in any one of the formats desired. In addition, detection of alarms can initiate a printout. A summary of printout of all points in alarm can be manually initiated.

INPUT/OUTPUT INTERFACE OPTIONS Where data records other than the integral printer are needed, interface options are available for: Paper tape punch, 7 Track Magnetic Tape, 9 Track Magnetic Tape, Teletype Writers, Line Printers, CRTs, Programmable Calculators, and RS-232-C/TTY interface for full bidirectional control.

Where the measurement data presented on the integral printer is the only record desired, a limit interface to other equipment can be provided. This option permits remote signals to control start of scan and scan-rate. Ouput from the Trendscan 1000 interface to external equipment is TTL compatible, serial by character, and includes measurement data with the following point status information: high or low alarm, open input or overload, last point indication, scan point and next scan point advance indication. Provision is also made for 4 digits of static data entry from external BCD switches.



EXPANDED TRENDSCAN SYSTEMS

The Trendscan 1000 can be combined with a Trendscan Alarm Processor to create a Data Acquisition System with extensive and flexible alarm capability. The Trendscan Alarm Processor is conveniently packaged in a 7" × 19" rack chassis and can be mounted with the Trendscan 1000 and related Input Frames in a variety of cabinets to provide a compact totally integrated system with broad data measurement and surveillance capacity.

The Trendscan Alarm Processor provides 64 or 128 programmable single or dual level alarms. Any one or more of the inputs from the Trendscan 1000 can be assigned at random to any one of these alarms.

Responses to alarms can take the form of illuminated LED indicators on the front panel, relay contact closures (made through screw type terminals on the rear of the chassis), and a serial BCD output.

Input and alarm assignments are programmed through an array of programming switches on the front panel into a solid state memory in the Alarm Processor—a memory which has a 1000 hour program retention time in the event of power loss. A locking switch with a removable key prevents tampering after the alarms have been programmed.

L&N FIELD OFFICES

AL, Birmingham
AL, Mobile
AZ, Phoenix (Tempe)
CA, Los Angeles (Anaheim)
CA, San Francisco (San Mateo)
CO, Denver
CT, Hartford (Avon)
DE, Wilmington
DC, Washington (Columbia)
FL, Jacksonville
FL, Lakeland
GA, Atlanta
IL, Chicago (Rosemont)
IL, South Holland
IN, Indianapolis
IA, Davenport (Bettendorf)
KS, Kansas City (Shawnee Mission)
KY, Louisville
LA, Baton Rouge
LA, Shreveport
MD, Baltimore (Columbia)
MA, Boston (Dedham)
MI, Detroit (Oak Park)
MI, Grand Rapids
MN, Minneapolis
MO, Kansas City (Shawnee Mission, KS)
MO, St. Louis (Clayton)
NC, Raleigh-Durham
NC, Winston-Salem
NE, Omaha
NJ, Union
NY, Albany (Latham)
NY, Buffalo
NY, New York (Union, NJ)
NY, Rochester
NY, Syracuse (Fayetteville)
OH, Akron (North Canton)
OH, Canton (North Canton)
OH, Cincinnati
OH, Cleveland (Wickliffe)
OH, Columbus
OH, Toledo
OK, Tulsa
OR, Portland
PA, Allentown (Bethlehem)
PA, Philadelphia (Fort Washington)
PA, Pittsburgh
PA, Sharon
SC, Columbia
TN, Knoxville
TN, Memphis
TX, Beaumont
TX, Dallas
TX, Houston
UT, Salt Lake City
VA, Richmond
VA, Roanoke
WA, Seattle (Bellevue)
WV, Charleston
WI, Milwaukee

Leeds & Northrup Company, Executive & Administrative Offices: Sumneytown Pike, North Wales, PA. 19454
Plants: North Wales, Colmar and Ellport, PA; Irondale, AL

INTERNATIONAL SUBSIDIARIES

Leeds & Northrup Australia, Pty., Ltd., Alexandria, N.S.W. Australia
Field Offices: Adelaide, Brisbane, Melbourne, Newcastle and Perth, Australia; Wellington, N.Z.

Leeds & Northrup Canada, Ltd., Rexdale (Toronto), Ontario, Canada
Field Offices: Calgary, Montreal

Leeds & Northrup Ltd., Birmingham, England
Field Offices: London, Sunderland

Leeds & Northrup GmbH, Dusseldorf, West Germany

Leeds & Northrup Italiana, S.p.A., Paderno Dugnano (Milano), Italy
Field Offices: Rome, Vicenza, Genoa, Naples, Taranto

Leeds & Northrup Mexicana S.A., Naucalpan de Juarez (Mexico City), Mexico
Field Office: Monterrey

Leeds & Northrup (Pty.) Ltd., Johannesburg, Rep. of South Africa

Leeds & Northrup S.A., Madrid, Spain

Agents in Principal Countries throughout the world

Cable Address: "LEEDSNORTH"

LEEDS & NORTHRUP
A UNIT OF GENERAL SIGNAL

North Wales, Pa. 19454

10-779gses

Printed in U.S.A.